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RICHMOND STATION, THE PHILADELPHIA ELECTRIC CO.

Fifth Boiler Unit Now in Operation at Kips Bay Station of New York Steam Corporation

By A. R. LUDT

Modern Power Practice in Belgium

By DAVID BROWNLIE

Other Articles in This Issue By

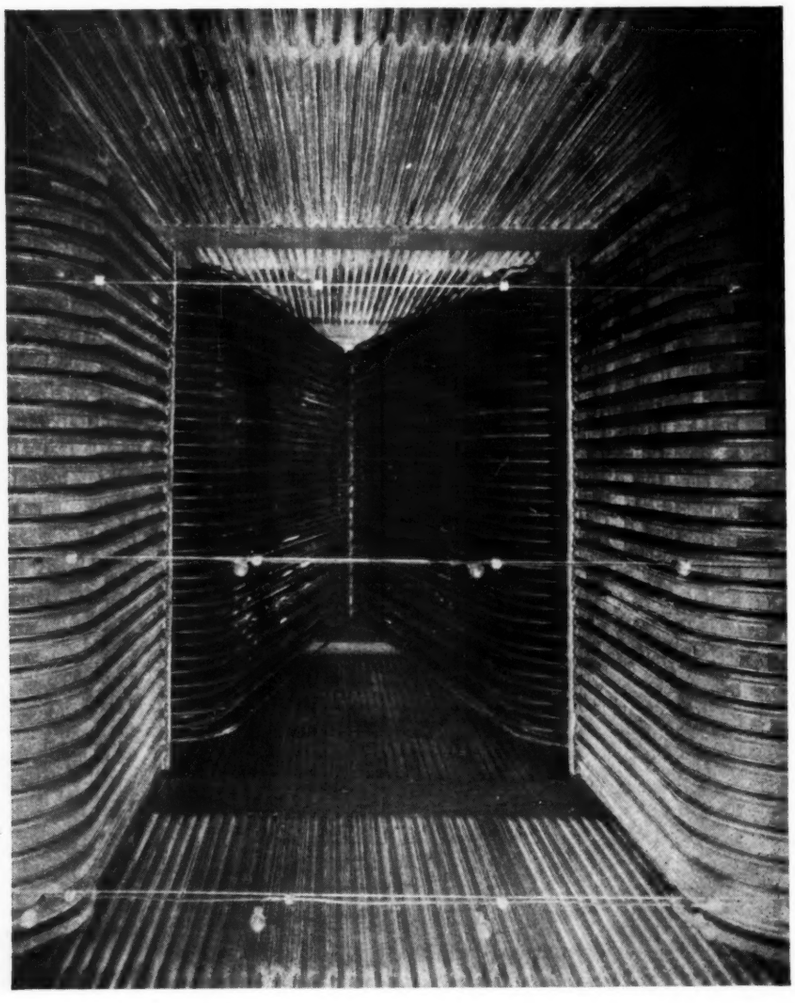
B. F. WOOD • E. G. GRADY • J. A. HOLMES • WM. L. DEBAUFRE • B. J. CROSS

C-E Water-Cooled Furnace Walls

Selected for New York's Largest Pulverized Fuel and Stoker Fired Plants

Every unit in the East River Station of the New York Edison Co. (New York's largest pulverized fuel fired plant) is equipped with C-E bare tube, water-cooled furnace walls.

The eight new units to be added to the Hudson Avenue Station of the Brooklyn Edison Company (New York's largest stoker fired plant) will also be equipped with C-E water-cooled furnace walls.



Interior of one of the furnaces at East River Station, looking up.

Over 500,000 sq. ft. of C-E bare tube water-cooled furnace walls are installed in the central station and industrial plants of this country.

COMBUSTION ENGINEERING CORPORATION

200 MADISON AVENUE NEW YORK, N. Y.

BOILERS - AIR PREHEATERS - STOKERS - PULVERIZED FUEL EQUIPMENT - WATER-COOLED FURNACES

COMBUSTION

VOLUME TWO • NUMBER SEVEN

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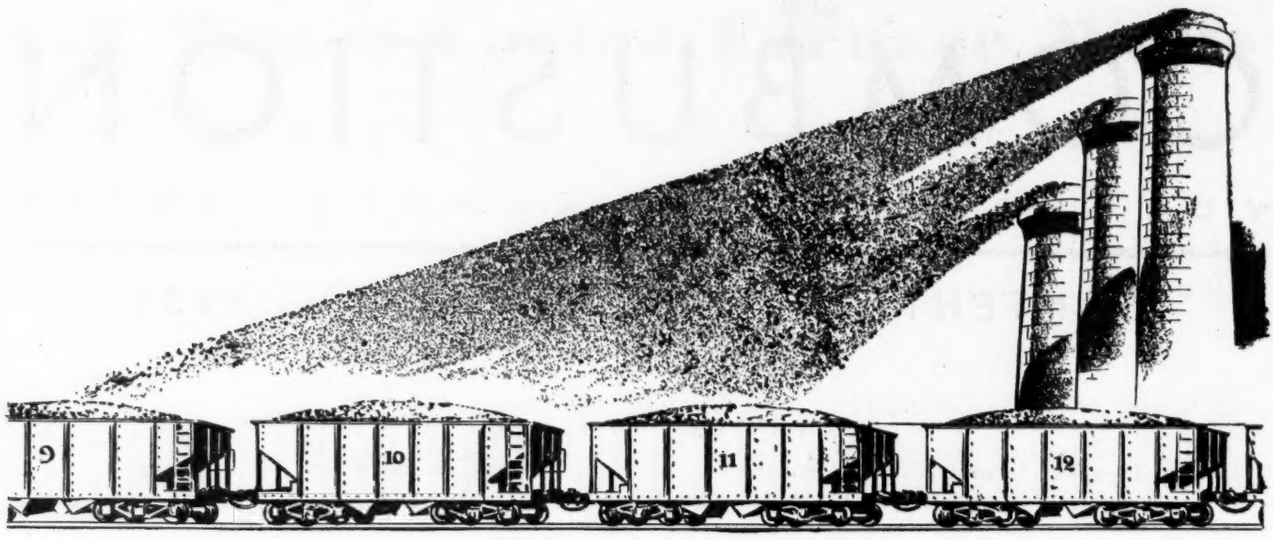

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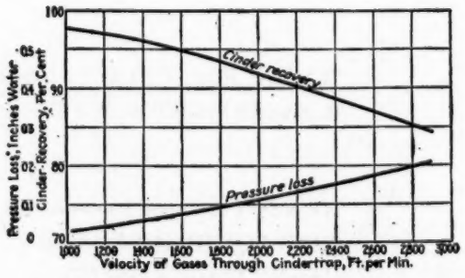
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Cinder recovery
Pressure loss
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COMBUSTION

VOLUME 2 . JANUARY 1931 . NUMBER 7

Trends in Steam Generating Practice

F. H. ROSENCRANTS

THE commercial success of nearly all developments requires the cooperative efforts of a manufacturer and an operating organization. Any such effort thrives best in a sympathetic atmosphere. The best personal relations between contact representatives, faith in the success of the undertaking, a division of risk and a distinct advantage to be gained from the success of the development by both parties are highly desirable factors. In such an atmosphere minor troubles are normal expectations; major difficulties become readily overcome; the full measure of ultimate success is attained.

The pace of progress during the twelve years since the war has been such as to test the ability of designing and operating organizations. The results stand as a testimonial to their initiative and courage. Major developments during this period include: pulverized fuel, water cooled furnaces, air preheating, stage extraction feed water heating, radiant heat superheaters, and the high pressure reheat cycle; developments which have been associated with rapid increase of unit capacity and of steam pressure and temperature.

In no instance has a successful major development been permitted to approach a state of perfection in advance of its general assimilation by the industry. It is inevitable, human nature being what it is, that the bad features of a new development are not emphasized and the good features are exaggerated. Were such not the case, progress would be slow and even though economic losses may result from premature adoption of an undeveloped idea, the more rapid development which results more than compensates the loss to the industry as a whole.

The idea of moderate pressure and higher temperature is at the moment competing for attention with the high pressure reheat cycle. What is to be the answer? Something over a year ago, in a paper presented before the World Power Conference Meeting in Tokyo, Japan, the writer was so bold as to make the following forecast, a forecast which still holds:

"In conclusion, the writer puts forward the forecast that future construction is likely to see a lessening interest in high pressure and an increase of interest in moderate pressure at a considerable increase in temperature."

The economic limits of high vacuum, high temperature and high pressure are being rapidly approached. Will engineers be satisfied with that? Renewed interest in the mercury-steam cycle and the keen interest displayed by engineers in a proposal of a combination binary-chemical cycle by Dr. Ing. E. Koenemann of Germany before the World Power Conference in Berlin indicate the contrary. Once the field of binary and combination binary-chemical cycles is definitely entered through the commercial success of any one form, it becomes difficult to predict the variety of forms in which it may ultimately appear.

It would appear that standardization (of other than parts and elements) in the power generating industry, however desirable a condition it might be from a manufacturing point of view, is not an immediate menace to the engineering profession associated therewith. Present schemes in process of development and new schemes which appear in the vista immediately ahead will require the same, or perhaps even a higher, degree of courage, skill and judgment to safely negotiate the pitfalls with which the field of rapid progress is always strewn, as that, which in the period since the war, has characterized the industry.

F. H. Rosencrants

Combustion Engineering Corporation New York

EDITORIAL

"Cheap" Repair Parts —a Costly Delusion

IN many organizations, an era of stringent economy prevails at the present time. Each requisition for supplies is carefully scrutinized; first, to determine the minimum of material required to keep the plant in operation, and, second, to make certain that those bare necessities which must be ordered are purchased at the lowest possible price.

Stocks of repair parts are lower than they have been in years and are, in many cases, inadequate to meet routine replacements. Thus, telegraphed orders, overtime work at the shops and express shipments are necessary to meet the needs of emergency replacements which, with a normal stock of repair parts on hand, would be simple details of plant maintenance. This is a costly kind of economy.

To meet these emergencies at the least expense, the plant manager often turns to the local foundry for help. Here he finds not only prompt deliveries but a price which may be as much as a cent a pound below that charged by the equipment manufacturer.

The immediate saving appears attractive.

The plea of economy is impelling.

"A penny saved is a penny earned" he argues and thus his repair part business goes to the local foundry.

Let us consider the incentives which the manufacturer of the original machine and the local foundry each has for giving service and furnishing correct replacement parts.

The maker of the original apparatus must uphold the reputation of his equipment by rendering efficient service and by supplying parts of the best material, correctly made and carefully tested.

His success and, in fact, the perpetuity of his business depend upon the satisfactory operation of the apparatus for whose design and performance he is responsible.

The local foundry, on the other hand, seeks tonnage—nothing more. All it offers is cast iron. Its only units of reckoning are pounds and cents.

Faulty stoker castings, which give inadequate grate motion and uneven air distribution, can easily effect a 10 per cent reduction in operating efficiency. If coal costs $5.00 a ton fired and stoker repairs average five cents per ton of coal burned, it is apparent that a saving of one cent on repair parts may represent a loss of fifty cents in fuel.

The user of the equipment and the manufacturer are virtually joint custodians of the manufacturer's reputation. The user expects the cooperation of the manufacturer in servicing his installation but when he goes into the open market for replacement parts, he neglects his part of the cooperation.

Such promiscuous purchasing of repair parts is not sound business. It violates the spirit of cooperation that should exist between maker and user long after the original sale and furthermore, it is actually false economy in plain dollars and cents.

Benjamin Franklin— Air Preheating Pioneer

ENGINEERING progress results mainly from new applications of known principles rather than from the introduction of ideas which are basically novel.

Ten years ago, air preheaters first gained commercial recognition in America as a means of gleaning heat from the boiler exit gases and returning that heat to the furnace to improve combustion conditions and increase the overall efficiency of the steam generating unit.

Heated combustion air has been extensively used in Europe for many years and the scheme is generally considered as a British development.

Benjamin Franklin's autobiography proves that the advantages of heating the air of combustion were known in America nearly two centuries ago and it suggests how the idea may have reached England.

Franklin relates,

"Having, in 1742, invented an open stove for the better warming of rooms, and at the same time saving fuel, as the fresh air admitted was warmed in entering . . .

"Gov'r Thomas was so pleas'd with the construction of this stove, that he offered to give me a patent for the sole vending of them for a term of years, but I declin'd it from a principle, that, as we enjoy great advantages from the inventions of others, we should be glad of an opportunity to serve others by any invention of ours; and this we should do freely and generously.

"An ironmonger in London however, making some small changes in the machine, which rather hurt its operation, got a patent for it there, and made, as I was told, a little fortune by it.

Franklin's altruistic attitude toward inventions is a bit too charitable for our present day commercial structure. However, his discovery of the advantages of "warming" the air entering the furnace and his application of this principle in his Franklin open stove, earn for him credit for contributing a basic idea of which our modern air preheaters are but new applications of an old principle.

Heat Absorption in Water-Cooled Furnaces*

By WM. L. DEBAUFR

International Combustion Engineering Corporation
New York

Based on the furnace heat balance, an empirical "effectiveness factor" is derived for water-cooled surfaces therein, relating the heat radiated by the burning fuel and products of combustion to the furnace-outlet temperature. The value of this factor is calculated from certain experimental data for turbulent horizontally fired pulverized-coal furnaces with bare water-cooled tube walls. For these experimental data, the fraction radiated of the heat liberated in the furnace has also been calculated and is compared with Broido's curve and with the value calculated by the Orrok-Hudson formula. The method of applying the effectiveness factor to design problems is illustrated by showing the effect of preheated-air temperature upon the furnace-outlet temperature.

WHEN "water screens" were installed in pulverized-fuel furnaces to prevent slagging of ash in the furnace bottoms, tests were made to determine the rate of heat absorption in order to design properly the downcomers and risers. These tests generally consisted in isolating certain tubes and passing water through them at a sufficient velocity to give a moderate temperature rise. In other cases, the "water screens" were connected to steam drums separate from the main steam drums of the boiler so that the steam generated therein could be measured. The rate of heat absorption so determined per square foot of water-cooled surface exposed to radiation, was compared with the operating capacity of the boiler in per cent of rating rather than attempting to connect the rate of heat absorption with the furnace temperature. This method of handling the problem was satisfactory as long as small portions only of the furnace walls were covered by water-cooled surfaces.

When larger portions of the refractory walls were replaced by water-cooled surfaces, a relation between rate of heat absorption and furnace temperature was based on these data and on an experiment by John Bell made some years previously, in which one of a first row of boiler tubes was replaced by a similar tube through which water was circulated and the temperature rise noted.[1]

With the development of steam generators in which the furnace walls are almost entirely replaced by water-cooled surfaces, it became desirable to have a relation which would more definitely proportion the total heat absorbed by the unit between the heating surface exposed to radiation in the furnace and the heating surface in the boiler tube banks. About that time appeared the timely papers upon the subject by Broido[2] and Wohlenberg,[3] with Orrok's discussions thereon. Broido and Orrok gave empirical relations for calculating the ratio of the heat absorbed by radiation to the heat liberated in the furnace, which relations were assumed to apply to all types of furnaces and conditions of operation; but the actual ratio might differ by 20 per cent from the calculated value. The paper by Wohlenberg showed how complicated the subject becomes when it is attempted to take account of all factors involved in the problem.

The idea was therefore conceived of applying a comparatively simple relation involving a factor which measures the effectiveness of the water-cooled surface and varies with the furnace design and the character of the fuel burned. This relation will be derived and applied to certain experimental data from pulverized-coal-fired furnaces. The method of applying the results to design problems will then be explained.

The above-mentioned relation is based on the furnace heat balance that the heat R radiated from the burning fuel and products of combustion plus the sensible heat P in the products leaving the furnace must equal the net heat B produced by burning the fuel plus the sensible heat A in the preheated air supplied for combustion; that is,

$$R + P = B + A$$

These heat quantities may be total hourly rates for the furnace in question, or may be based on one square foot of water-cooled surface in the furnace or on one pound of fuel fired.

Due to unburnt combustible in the ashes and flue dust, the heat B actually liberated in the furnace is

*Paper presented at the Annual Meeting of The American Society of Mechanical Engineers, New York, Dec. 1 to 5, 1930. Contributed by the Fuels Division.

[1] "An Outline of the Theory of Heat Transmission and Absorption in Application to Ordinary Engineering Problems." Proceedings of the Engineers' Society of Western Pennsylvania, vol. 32 (1916), pp. 797-845.

[2] "Radiation in Boiler Furnaces," B. N. Broido. Trans. A.S.M.E., vol. 47 (1925), pp. 1123-1177.

[3] "Radiation in the Pulverized-Fuel Furnace," W. J. Wohlenberg. Trans. A.S.M.E., vol. 47 (1925), pp. 127-176.

less than the calorimeter heating value of the fuel, which is accordingly reduced by 14,600 times the fraction of a pound of unburnt carbon per pound of fuel fired. A further reduction is made equal to the heat required to evaporate the moisture in the fuel and that formed from the hydrogen burned. The latent heat of this water vapor is taken as approximately 1050 B.t.u. per lb. at room temperature. That is,

$$B = H - 14{,}600 \times C - 1050 \times M$$

Where H = gross calorimeter heating value of the fuel fired, B.t.u. per lb.

C = lb. unburnt carbon per lb. of fuel fired, and

M = lb. moisture in fuel and formed from hydrogen per lb. of fuel fired.

The latent heat of the water vapor could be added to the sensible heat P in the products of combustion leaving the furnace instead of being subtracted from the gross heating value of the fuel fired. The latter method is preferred, however, because it is considered more logical to base the heat radiated upon the net heat liberated in the furnace than upon the gross heating value of the fuel. Also, it is customary abroad to base the efficiency of steam-generating equipment upon the net heating value of the fuel rather than penalize the steam power plant in comparison with the internal-combustion power plant by using the gross heating value of the fuel, as is done in this country.

The sensible heat A in the preheated air is calculated from the amount of air supplied for combustion,

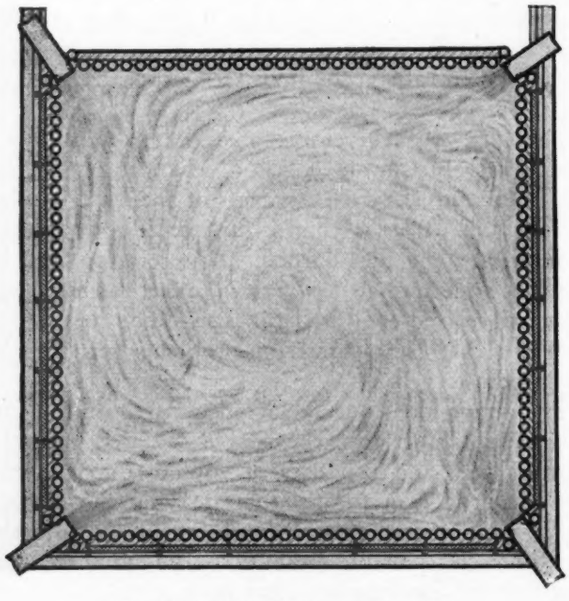

Fig. 1—Horizontal tangential firing.

the portion of it which is preheated, and the temperature to which it is preheated. The quantity of air supplied per pound of fuel fired may be calculated from the analysis of the products of combustion leaving the furnace, the composition of the fuel fired, and the loss of combustible in the ashes and flue dust. The sum of A and B is the net heat available for radiation in the furnace and for heating the products of combustion to the furnace-outlet temperature.

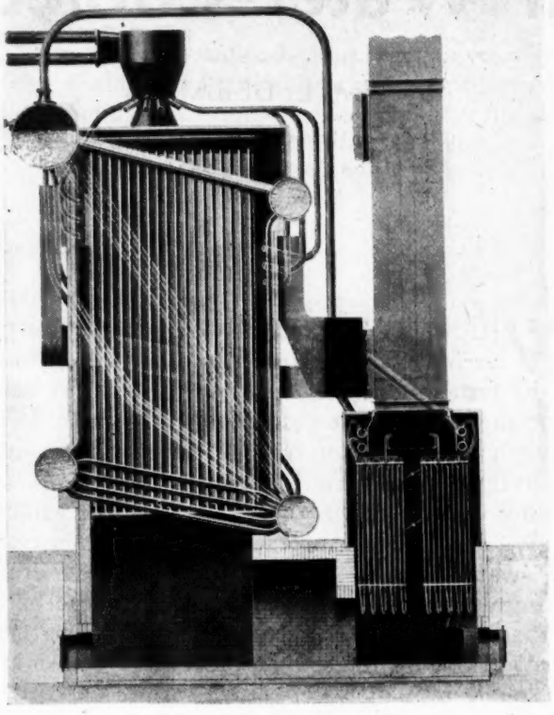

Fig. 2—Water-cooled furnace at Manchester, England.

The sensible heat S in the products of combustion may be calculated for the composition and temperature of the products leaving the furnace. The heat R radiated is then found by difference.

Now, the more effective the water-cooled surfaces in absorbing heat within the furnace, the larger must be R and the lower must be the temperature of the products leaving the furnace. Hence, the ratio of R to some function of the furnace-outlet temperature is an "effectiveness factor" for the water-cooled surfaces within the furnace. As the effectiveness of these surfaces must vary with their arrangement and condition, the effectiveness factor will show by its variations, the effect of such changes rather than be a universal constant which will apply under all conditions.

The temperature function which has been chosen as a basis for calculating the effectiveness factor of the water-cooled surfaces is the fourth power of the absolute temperature of the products of combustion leaving the furnace minus the fourth power of the absolute temperature of the water evaporating within the water-cooled surfaces. The effectiveness factor E may be employed to calculate the heat R radiated per pound of fuel fired by means of the relation:

$$R = \frac{E}{F}\left[\left(\frac{T_G}{1000}\right)^4 - \left(\frac{T_S}{1000}\right)^4\right]$$

where T_G = absolute temperature of the products of combustion leaving the furnace, deg. fahr.

T_S = absolute temperature of the water evaporating into steam within the water-cooled surfaces, deg. fahr.

F = fuel fired per hour per square foot of water-cooled surface exposed to radiation, lb.

R = heat radiated per lb. of fuel fired in B.t.u.; and

E = effectiveness factor of the water-cooled surfaces.

There are a number of reasons why the heat radiated by the burning fuel and products of combustion to the water-cooled surfaces should not be proportional to the difference of the fourth powers of the furnace-outlet absolute temperature and the absolute steam temperature; thus:

The temperature of the burning fuel and products of combustion within the furnace is not uniform, but varies from a maximum at the place of most intense combustion, to a minimum generally at the furnace outlet.

The water-cooled surfaces absorbing radiant heat are at a higher temperature than the water evaporating into steam within these surfaces.

Some heat may pass by convection and conduction rather than by radiation.

Radiation from non-luminous gases does not follow

TABLE 1—EXPERIMENTAL DATA FROM PULVERIZED-COAL FURNACES

Location of furnace	Furnace volume, cu. ft.	Water-cooled surface exposed to radiation, sq. ft.	Date of test	Run number	Coal fired per hour, lb.	Coal fired per hr. per cu. ft. of furnace volume, lb.	Coal fired per hr. per sq. ft. of water-cooled surface, lb.	Gross heating value per lb. of coal, B.t.u.	Gross heat liberation per hr. per cu. ft. of furnace volume, B.t.u.	Gross heat liberation per hr. per sq. ft. of water-cooled surface, B.t.u.	Volatile matter in coal as fired, per cent	Sulphur in coal as fired, per cent	Hydrogen in coal as fired, per cent	Carbon in coal as fired, per cent	Nitrogen in coal as fired, per cent	Oxygen in coal as fired, per cent	Moisture in coal as fired, per cent	Ash in coal as fired, per cent	Fusion temperature of ash, deg. fahr.	Pulverized coal through 40 mesh, per cent	Pulverized coal through 60 mesh, per cent	Pulverized coal through 100 mesh, per cent	Pulverized coal through 200 mesh, per cent	Pulverized coal through 325 mesh, per cent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
			1926																					
			6-21	1	5,706	2.15	4.67	11,947	25,700	55,800	28	1.0	4.0	73.0	1.5	2.5	9.0	9.0	..	99.7	..	88.8	69.4	..
			6-22	2	4,605	1.74	3.77	12,198	21,200	46,000	28	1.0	4.0	73.0	1.5	2.5	9.0	9.0	..	98.8	..	78.2	58.3	..
			6-24	5	7,485	2.82	6.12	12,327	34,700	75,400	28	1.0	4.0	73.0	1.5	2.5	9.0	9.0	..	99.6	..	78.8	53.3	..
Manchester, England	2,653	1223	6-26	6	5,808	2.19	4.75	12,391	27,100	58,800	28	1.0	4.0	73.0	1.5	2.5	9.0	9.0	..	99.1	..	77.4	55.0	..
			6-26	7	7,299	2.75	5.97	12,236	33,600	73,000	28	1.0	4.0	73.0	1.5	2.5	9.0	9.0	..	99.3	..	85.0	64.3	..
			6-28	8	7,856	2.96	6.42	12,104	35,800	77,700	28	1.0	4.0	73.0	1.5	2.5	9.0	9.0	..	99.8	..	81.7	51.4	..
			6-29	9	7,304	2.75	5.97	12,308	33,900	73,400	28	1.0	4.0	73.0	1.5	2.5	9.0	9.0	..	99.8	..	83.5	49.7	..
			1927																		30 mesh	50 mesh		
			3-22	2	5,600	2.11	4.58	11,978	25,600	54,800	34	1.03	4.69	66.37	1.26	9.31	12.14	5.20	2282	99.4	94.0	80.0	61.5	..
			3-23	3	7,724	2.91	6.32	11,485	33,400	72,600	34	1.00	4.54	64.18	1.22	9.01	14.19	5.86	2282	99.3	92.3	81.6	58.7	..
Manchester, England	2,653	1223	3-24	4	5,302	2.00	4.33	11,808	23,600	51,200	34	1.02	4.65	65.68	1.25	9.22	12.52	5.66	2282	99.4	93.0	76.0	57.4	..
			3-25	5	5,827	2.20	4.77	11,638	25,600	55,500	34	1.01	4.59	64.86	1.24	9.10	13.86	5.34	2282	99.3	92.8	74.0	55.9	..
			1929																					
			3-27	1	8,260	2.08	4.28	12,375	25,800	53,000	34.7	1.37	4.28	68.97	1.10	8.62	6.20	9.46	..	..	96.9	89.3	67.3	..
			4-2	2	7,820	1.98	4.06	12,880	25,420	52,100	32.8	1.50	4.14	71.73	1.32	7.96	5.75	7.60	2340	..	96.9	89.3	67.3	..
			4-3	3	8,375	2.12	4.35	12,880	27,300	56,100	32.8	1.50	4.14	71.73	1.32	7.96	5.75	7.60	2340	..	96.9	89.3	67.3	..
			4-3	4	8,450	2.14	4.38	12,880	27,500	56,500	32.8	1.50	4.14	71.73	1.32	7.96	5.75	7.60	2340	..	96.9	89.3	67.3	..
			4-12	5	9,100	2.30	4.72	12,880	29,600	60,750	32.8	1.50	4.14	71.73	1.32	7.96	5.75	7.60	2340	..	96.9	89.3	67.3	..
			1929																					
			11-6	1	28,200	1.50	5.84	13,974	21,000	81,600	20.31	0.61	4.20	79.93	1.10	2.95	3.18	8.03	2300	..	..	92	75	26
			11-7	2	32,140	1.71	6.66	14,066	24,100	93,600	20.30	0.62	4.24	80.76	1.16	2.99	4.52	5.71	2290	..	..	86	69	46
			11-8	3	20,910	1.11	4.33	14,070	15,600	60,900	20.98	0.57	4.37	80.05	1.12	3.38	5.10	5.41	2270	..	..	93	78	40
			11-11	4	21,330	1.13	4.42	14,080	16,000	62,400	20.82	0.59	4.36	80.57	1.13	3.03	4.34	5.80	2270	..	..	89	70	32
			11-12	5	18,875	1.00	3.91	13,919	13,900	54,400	19.56	0.65	4.36	79.49	1.13	3.01	4.30	7.06	2320	..	..	90	74	36
			11-13	6-A	31,800	1.69	6.59	14,003	23,700	92,300	20.26	0.57	4.37	79.74	1.14	3.02	5.46	5.70	2300	..	..	91	69	33
Hell Gate Power Plant, New York	18,800	4827	11-13	6-B	31,800	1.69	6.59	14,003	23,700	92,300	20.26	0.57	4.37	79.74	1.14	3.02	5.46	5.70	2300	..	..	79	65	33
			11-14	6-C	31,800	1.69	o.59	14,003	23,700	92,300	20.26	0.57	4.37	79.74	1.14	3.02	5.46	5.70	2300	..	..	88	69	23
			11-14	7-A	20,920	1.11	4.33	13,827	15,300	59,900	20.80	0.61	4.28	70.05	1.13	2.61	5.74	6.58	2280	..	..	92	78	44
			11-14	7-B	20,920	1.11	4.33	13,827	15,300	59,900	20.80	0.61	4.28	70.05	1.13	2.61	5.74	6.58	2280	..	..	92	77	43
			11-14	7-C	20,920	1.11	4.33	13,827	15,300	59,900	20.80	0.61	4.28	70.05	1.13	2.61	5.74	6.58	2280	..	..	84	60	41
			11-14	7-D	20,920	1.11	4.33	13,827	15,300	59,900	20.80	0.61	4.28	70.05	1.13	2.61	5.74	6.58	2280	..	..	92	76	38
			11-15	8	16,000	0.85	3.31	13,827	11,800	45,800	20.80	0.61	4.28	70.05	1.13	2.61	5.74	6.58	2280	..	..	88	66	48
			1930																		40 mesh	60 mesh		
			1-22	1	37,620	2.01	8.12	14,090	28,340	114,400	35.03	1.08	4.73	78.59	1.27	7.15	1.02	6.21	2320	88	74	68	30	2
			1-23	2	34,610	1.85	7.47	13,970	25,830	104,400	35.05	1.07	4.71	78.28	1.21	7.11	0.87	6.75	2320	98	92	84	60	32
Kip's Bay Steam Plant, New York	18,705	4635	1-24	3	30,130	1.61	6.50	14,000	22,550	91,000	34.63	1.07	4.71	78.26	1.21	7.12	1.02	6.61	2320	100	90	82	64	34
			1-25	4	26,190	1.40	5.65	13,960	19,530	78,900	34.15	1.07	4.70	78.01	1.21	7.10	1.08	6.83	2320	99	94	84	56	22
			1-25	5	21,960	1.17	4.74	13,900	16,310	65,900	34.27	1.07	4.69	77.88	1.21	7.09	1.24	6.82	2320	98	88	86	40	16

TABLE 1 Continued

Unburnt carbon loss per lb. of coal as fired, B.t.u.	Heat to evaporate moisture per lb. of coal as fired, B.t.u.	Net heat liberation per lb. of coal as fired, B.t.u.	CO_2 in products of combustion leaving the furnace, per cent	CO in products of combustion leaving furnace, per cent	O_2 in products of combustion leaving furnace, per cent	N_2 in products of combustion leaving furnace, per cent	Products of combustion leaving furnace per lb. of coal fired, lb.	Air supplied for combustion per lb. of coal fired, lb.	Excess air, per cent	Portion of air preheated, per cent	Preheated air temperature, deg. fahr.	Sensible heat in preheated air per lb. of coal fired, B.t.u.	Heat radiated and in products per lb. of coal fired, B.t.u.	Furnace outlet temperature, deg. fahr.	Sensible heat in products of combustion per lb. of coal fired, B.t.u.	Heat radiated per lb. of coal fired, B.t.u.	Heat radiated per hr. per sq. ft. of water-cooled surface, B.t.u.	Fraction radiated of gross heat liberation	Net heat available per hr. per sq. ft. of water-cooled surface, B.t.u.	Fraction radiated of net heat liberation	Steam pressure, gage, lb.	Saturated steam temperature, deg. fahr.	$\left(\frac{Ta}{1000}\right) - \left(\frac{Ts}{1000}\right)$	Effectiveness factor of water-cooled surface
(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)
522	473	10,952	13.5	...	5.5	81.0	13.72	12.84	31.0	90.1	735	1884	12,836	1680	5827	7099	32,730	0.587	59,900	0.548	264	410	20.40	1600
554	473	11,171	12.1	...	6.9	81.0	15.18	14.30	45.8	89.4	746	2116	13,287	1721	6591	6596	25,240	0.449	50,100	0.504	272	413	22.04	1150
616	473	11,238	15.3	...	3.7	81.0	12.24	11.36	15.9	91.0	795	1839	13,077	1888	5953	7124	43,600	0.578	80,000	0.545	280	416	29.81	1460
365	473	11,553	14.3	...	4.7	81.0	13.02	12.14	23.9	89.4	758	1830	13,383	1805	6006	7377	35,040	0.596	63,600	0.551	288	418	25.72	1360
278	473	11,485	14.7	...	4.3	81.0	12.69	11.81	20.5	78.8	860	1804	13,289	2130	7060	6229	37,190	0.509	79,300	0.469	255	408	44.43	840
394	473	11,237	15.1	...	3.9	81.0	12.39	11.51	17.4	79.8	857	1775	13,012	2162	7008	6004	38,550	0.496	83,500	0.462	285	417	46.67	830
329	473	11,506	14.8	...	4.2	81.0	12.62	11.74	19.7	79.2	870	1835	13,331	2250	7462	5869	35,040	0.477	79,600	0.440	308	424	53.33	660
348	570	11,060	16.0	0	3.1	80.9	10.94	10.01	15.2	77.4	515	810	11,870	1860	5301	6578	30,130	0.550	54,400	0.554	215	394	28.44	1060
242	578	10,665	15.5	0	3.7	80.8	11.02	10.10	15.3	84.9	608	1090	11,756	2070	6018	5738	36,240	0.499	74,300	0.468	247	405	40.41	900
235	571	11,002	15.3	0	3.5	80.8	11.40	10.47	20.8	73.6	520	822	11,824	1965	5860	5964	25,820	0.494	51,200	0.504	229	399	34.04	780
315	580	10,743	15.9	0	3.2	80.9	10.81	9.88	16.3	75.8	590	928	11,671	2084	5958	5713	27,250	0.491	55,700	0.489	213	393	41.36	660
220	470	11,685	15.5	0	..	...	11.88	10.89	19.0	95.0	600	1341	13,026	1580	4663	8363	35,790	0.675	55,800	0.641	220	396	16.68	2150
190	452	12,238	15.5	0	..	...	12.37	11.35	19.8	95.1	580	1346	13,584	1600	4911	8673	35,210	0.676	55,200	0.638	228	399	17.46	2020
190	452	12,238	16.3	0	..	...	11.83	10.81	14.1	95.0	580	1281	13,519	1660	4900	8619	37,490	0.668	58,800	0.638	228	399	19.66	1910
190	452	12,238	16.3	0	..	...	11.83	10.81	14.1	94.8	580	1278	13,516	1585	4654	8862	38,820	0.687	59,200	0.656	228	399	16.95	2290
190	452	12,238	16.0	0	..	...	12.02	11.01	16.2	93.6	640	1437	13,675	1680	5046	8629	40,730	0.671	64,500	0.631	235	401	20.42	1990
187	427	13,360	13.57	0	5.63	80.80	15.24	14.34	36.4	76.0	180	291	13,651	1813	7052	6509	38,540	0.472	79,700	0.484	280	416	26.10	1470
213	451	13,402	13.91	0	5.43	80.86	15.02	14.12	33.2	80.5	214	398	13,800	1854	7202	6598	43,040	0.469	91,900	0.478	280	416	28.08	1560
97	468	13,505	13.34	0	5.90	80.76	15.67	14.74	38.5	69.1	185	284	13,789	1705	6770	7019	30,390	0.499	59,700	0.509	280	416	21.38	1430
197	452	13,477	13.34	0	5.78	80.78	15.64	14.65	37.5	69.8	180	273	13,750	1638	6490	7260	32,090	0.514	60,800	0.528	280	416	18.79	1710
213	452	13,254	13.36	0	5.86	80.78	15.38	14.47	38.0	66.9	161	214	13,468	1686	6559	6909	27,010	0.497	52,700	0.513	280	416	20.62	1310
200	476	13,327	15.35	0	3.62	81.03	13.62	13.68	20.5	80.3	185	284	13,611	1861	6531	7080	46,660	0.506	89,700	0.520	280	416	28.43	1640
86	476	13,441	14.02	0	5.10	80.88	14.95	13.99	31.8	80.2	184	311	13,752	1842	7051	6701	44,160	0.478	90,600	0.487	280	416	27.49	1610
222	476	13,305	11.94	0	7.48	80.58	17.14	16.19	56.9	68.9	189	375	13,680	1817	7925	5752	37,910	0.411	90,200	0.420	280	416	26.29	1440
93	465	13,269	15.09	0	3.91	81.00	13.82	12.89	22.5	68.9	214	311	13,580	1768	6259	7321	31,700	0.529	58,800	0.539	280	416	24.05	1320
69	465	13,293	13.74	0	5.42	80.84	15.11	14.17	34.4	69.0	204	319	13,612	1732	6656	6956	30,120	0.503	58,900	0.511	280	416	22.50	1340
75	465	13,287	12.64	0	6.69	80.67	16.31	15.37	45.8	68.9	197	327	13,614	1715	7086	6528	28,270	0.472	58,900	0.480	280	416	21.79	1300
51	465	13,311	11.49	0	7.90	80.52	17.85	16.91	60.1	69.1	211	401	13,712	1676	7539	6173	26,730	0.446	59,400	0.450	280	416	20.23	1320
273	465	13,089	12.47	0	6.88	80.65	16.25	15.31	47.3	..	..	0	13,080	1645	6757	6332	20,960	0.457	43,300	0.484	280	416	19.05	1100
150	458	13,482	13.1	0	5.1	81.8	15.54	14.60	40.3	67.7	609	1306	14,788	2366	9693	5095	41,370	0.362	120,100	0.344	285	417	63.19	655
95	454	13,421	12.9	0	5.0	82.1	15.77	14.84	42.6	59.2	590	1121	14,542	2231	9175	5367	40,090	0.384	108,600	0.369	284	417	51.85	773
62	456	13,482	12.5	0	5.5	82.0	16.28	15.35	47.2	56.3	574	1068	14,550	2156	9112	5438	35,350	0.389	94,600	0.374	283	417	46.24	764
104	455	13,401	12.3	0	5.9	81.8	16.42	15.50	49.5	46.2	516	782	14,183	2113	8980	5203	29,400	0.373	80,100	0.367	275	414	43.25	680
170	456	13,274	15.1	0	2.9	82.0	13.50	12.58	22.3	41.2	474	515	13,789	2072	7301	6488	30,750	0.467	65,400	0.470	275	414	40.52	780

the fourth-power law, and radiation from burning fuel may not follow this law.

The flames may not entirely fill the furnace volume.

Clouds of cool, unburnt fuel may intervene between the hot flames and part of the water-cooled surface.

Combustion may not be complete within the furnace, but continue into and through the boiler-tube banks.

All of these discrepancies affect the effectiveness

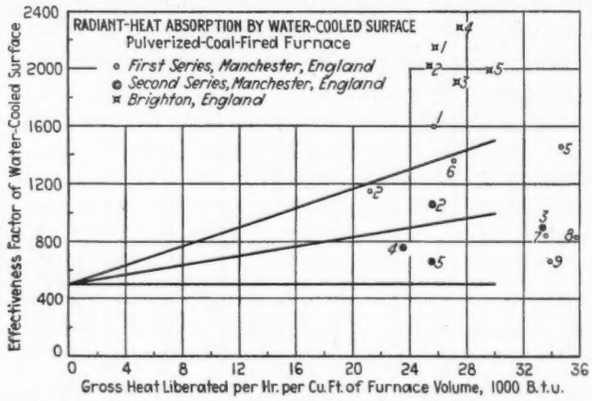
RADIANT-HEAT ABSORPTION BY WATER-COOLED SURFACE
Pulverized-Coal-Fired Furnace
First Series, Manchester, England
Second Series, Manchester, England
Brighton, England
Effectiveness Factor of Water-Cooled Surface
Gross Heat Liberated per Hr. per Cu. Ft. of Furnace Volume, 1000 B.t.u.

Fig. 3—Effectiveness factors for water-cooled furnaces at Manchester and Brighton, England.

factor when the above relation is applied to determine its value for any set of experimental conditions. All of them, however, depend mainly if not entirely upon the characteristics of the fuel, the arrangement and condition of the furnace, and the capacity at which it is operated. Hence, the effectiveness factor determined by the above relation should apply to similar fuels, similar furnace arrangements, and equal capacities.

The effectiveness factor will also vary with the way in which the water-cooled surface exposed to radiation is measured. While the projected area is the simplest way of measuring such surfaces, actual exposed areas have been employed, partly because it has been customary to measure these surfaces in this way, but also because the actual areas were considered to give a better comparative measure of the heat absorbed, for example, by the first rows of boiler tubes and by furnace-wall tubes. Two-thirds of the surface of the first row of boiler tubes and one-third of the surface of the second row have been taken as exposed to radiation. Two-thirds of the surface of the "screen tubes," which are usually widely spaced, has been taken as exposed to radiation. When a wall is made up of plain tubes closely spaced, the exposed area has been taken as one-half of the tube surface. If widely spaced in front of a refractory wall, two-thirds of the surface has been taken. For fin tubes, the actual area of tube and fins on the furnace side has been taken as exposed to radiation.

Table 1 gives experimental data from four pulverized-coal-fired furnaces in which all sides of the furnaces are nearly completely water-cooled by bare tubes, and in which tangential firing is used as illustrated in Fig. 1.

The first furnace is that of the Wood steam generator located at Manchester, England. This furnace, as shown in Fig. 2, has the dimensions: width, 12 ft. 6 in.; depth, 12 ft. 0 in.; height, 18 ft. 9 in. It was fired near the top by burners located in the four corners of the furnace. The effectiveness factor is plotted in Fig. 3. In run 1, the furnace was comparatively clean, with a resultant factor of 1600. In run 2, a lower factor was obtained at a reduced rating. Runs 3 and 4 were not completed. In runs 5 and 6, the factor was around 1400. When runs 7, 8, and 9 were made, considerable amounts of slag had collected in the furnace, thereby accounting for the low factors around 800 and 700. The second series of runs with this furnace showed the same drop in the effectiveness factor from run to run as slag accumulated in the furnace.

In the second steam generator, installed at Brighton, England, the furnace walls were kept in a very clean condition by use of steam-jet blowers. Factors of 2000 and more were obtained, as shown by the points plotted in Fig. 3. These factors indicate the effectiveness of unusually clean furnace surfaces. The arrangement of the furnace at Brighton is similar to the one at Manchester shown in Fig. 2.

The data from the third furnace at Hellgate show the effectiveness of water-cooled surfaces in a large furnace operated with good coal at moderate combustion rates. This furnace is 26 ft. 5 in. by 25 ft. 1 in., making a cross-sectional area of 662 sq. ft. The effectiveness factors are plotted in Fig. 4 and indicate a falling off in effectiveness of the surface as the rate of heat liberation is reduced.

The fourth furnace, Fig. 5, has about the same

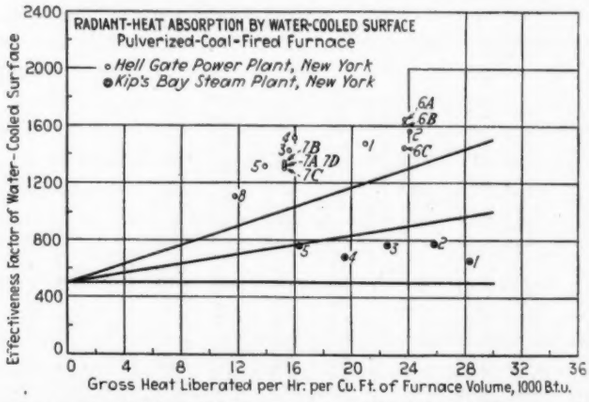
RADIANT-HEAT ABSORPTION BY WATER-COOLED SURFACE
Pulverized-Coal-Fired Furnace
Hell Gate Power Plant, New York
Kip's Bay Steam Plant, New York
Effectiveness Factor of Water-Cooled Surface
Gross Heat Liberated per Hr. per Cu. Ft. of Furnace Volume, 1000 B.t.u.

Fig. 4—Effectiveness factors for water-cooled furnaces at Hell Gate Power Plant and Kips Bay Steam Plant.

volume as the third furnace, but is higher with a somewhat less cross-sectional area, being 20 ft. 4 in. by 28 ft. 4 in. with a corresponding cross-sectional area of 576 sq. ft. The effectiveness factor is less than for the third furnace, due probably to a thicker layer of slag adhering to the furnace walls.

In view of these and other data, a factor of 1500 has been selected for clean or but slightly dirty furnaces with rates of combustion around 28,000 to 30,000 B.t.u. per hr. per cu. ft. of furnace volume. As the rate of heat liberation is reduced, the factor is taken to drop off in a straight-line relation, as indicated in Figs. 3 and 4, to a value of 500 at zero heat liberation. For a moderately dirty furnace, a factor of 1000 is used at the maximum combustion rate. For a considerable amount of slag adhering to the furnace walls, the factor is taken as 500 for all rates of heat liberation.

TABLE 2 — HEAT RADIATED PER SQUARE FOOT OF WATER-COOLED SURFACE, B.T.U. PER HR.
(Steam pressure, 450 lb. gage)

Furnace-outlet temperature, deg. fahr.	For effectiveness factor of 1500	1250	1000	750	500
1000	5,742	4,785	3,828	2,871	1,914
1100	7,809	6,508	5,206	3,904	2,603
1200	10,315	8,596	6,877	5,158	3,439
1300	13,318	11,098	8,879	6,659	4,439
1400	16,879	14,066	11,252	8,439	5,626
1500	21,062	17,552	14,042	10,531	7,021
1600	25,938	21,615	17,292	12,969	8,646
1700	31,577	26,314	21,051	15,789	10,526
1800	38,057	31,714	25,371	19,028	12,686
1900	45,456	37,880	30,304	22,728	15,152
2000	53,858	44,882	35,906	26,929	17,953
2100	63,350	52,792	42,233	31,675	21,117
2200	74,022	61,685	49,348	37,011	24,674
2300	85,967	71,639	57,311	42,984	28,656
2400	99,284	82,737	66,190	49,642	33,095
2500	114,074	95,062	76,049	57,037	38,025
2600	130,441	108,701	86,961	65,221	43,480
2700	148,494	123,745	98,996	74,247	49,498
2800	168,345	140,288	112,230	84,172	56,115
2900	190,109	158,424	126,739	95,054	63,370
3000	213,905	178,254	142,603	106,952	71,302

TABLE 3 — FRACTION RADIATED FROM ORROK-HUDSON FORMULA

Furnace	Run No.	Fraction radiated by formula	Deviation based on gross heat liberated	Deviation based on net heat available
Manchester, England	1	0.494	—0.093	—0.052
	2	0.494	—0.055	—0.010
	5	0.490	—0.088	—0.055
	6	0.504	—0.092	—0.047
	7	0.484	—0.025	+0.015
	8	0.482	—0.014	+0.020
	9	0.485	+0.008	+0.045
Manchester, England	2	0.558	+0.008	+0.004
	3	0.514	+0.015	+0.026
	4	0.553	+0.049	+0.049
	5	0.557	+0.066	+0.068
Brighton, England	1	0.545	—0.130	—0.096
	2	0.541	—0.135	—0.097
	3	0.544	—0.124	—0.094
	4	0.544	—0.143	—0.112
	5	0.531	—0.140	—0.100
Hell Gate Power Plant, New York	1	0.438	—0.034	—0.046
	2	0.426	—0.043	—0.052
	3	0.468	—0.031	—0.041
	4	0.467	—0.047	—0.061
	5	0.485	—0.012	—0.028
	6-A	0.453	—0.053	—0.067
	6-B	0.429	—0.049	—0.058
	6-C	0.394	—0.017	—0.026
	7-A	0.502	—0.027	—0.037
	7-B	0.478	—0.025	—0.033
	7-C	0.458	—0.014	—0.022
	7-D	0.434	—0.012	—0.016
	8	0.484	+0.027	0
Kips Bay Steam Plant, New York	1	0.394	+0.032	+0.050
	2	0.400	+0.016	+0.031
	3	0.409	+0.020	+0.035
	4	0.423	+0.050	+0.056
	5	0.496	+0.029	+0.026

Table 2 shows how the heat radiated by the burning fuel and products of combustion varies with the furnace-outlet temperature for several values of the effectiveness factor. These results are based on a steam pressure of 450 lb. gage, with a corresponding saturated steam temperature of 460 deg. fahr. Slightly higher results would be calculated for lower steam pressures and the reverse for higher steam pressures.

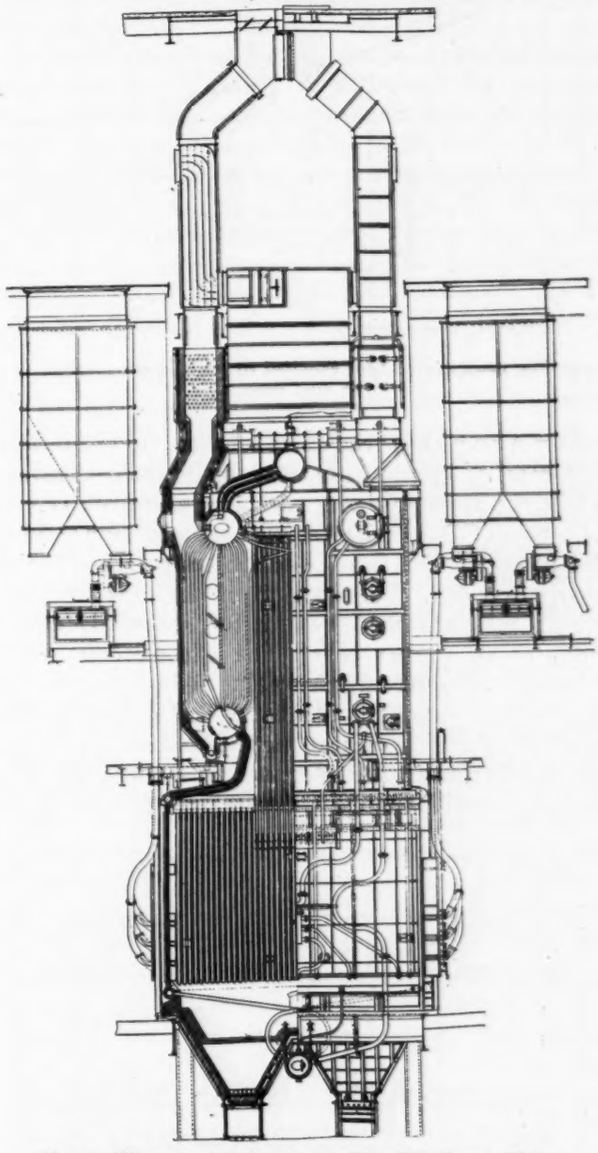

Fig. 5—Water-cooled furnace at Kips Bay Steam Plant, New York City.

For example, with a furnace-outlet temperature of 2000 deg. fahr., the calculated heat radiated would be 0.7 per cent higher for 125 lb. steam pressure and 1.4 per cent lower for 1400 lb. steam pressure than tabulated.

In addition to the effectiveness factor, Table 1 also contains the ratios of the heat radiated to the gross heating value of the fuel and to the net heat liberated and in the preheated air. These ratios are plotted in

Figs. 6 and 7, respectively, in which Broido's curve has been drawn for comparison.

Table 3 contains the ratios calculated by Hudson's formula as modified by Orrok, and the deviations from the experimental values.

One particularly interesting set of data is found in

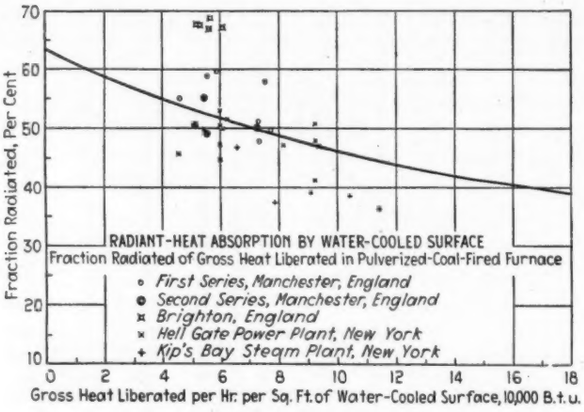
Fraction Radiated, Per Cent
RADIANT-HEAT ABSORPTION BY WATER-COOLED SURFACE
Fraction Radiated of Gross Heat Liberated in Pulverized-Coal-Fired Furnace
First Series, Manchester, England
Second Series, Manchester, England
Brighton, England
Hell Gate Power Plant, New York
Kip's Bay Steam Plant, New York
Gross Heat Liberated per Hr. per Sq. Ft. of Water-Cooled Surface, 10,000 B.t.u.

Fig. 6—Ratio of heat radiated to gross heating value of fuel fired.

runs 7-A to 7-D for the third furnace. In these runs, the rate of combustion was maintained constant while the air supply was varied to give from 11.5 to 15 per cent CO_2 in the products of combustion leaving the furnace. The furnace-outlet temperature varied nearly 100 deg. The fraction of the heat liberated which was absorbed by the furnace walls varied from 45 to 53 per cent. The effectiveness factor averaged 1320, having this value at both the lowest and highest quantities of air supplied for combustion and differing by 20 only above and below the average. As a variation in the effectiveness factor from 1500 to 1000 would change the furnace-outlet tempera-

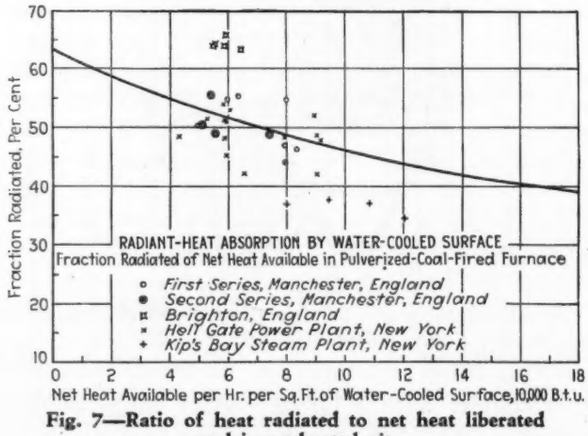
Fraction Radiated, Per Cent
RADIANT-HEAT ABSORPTION BY WATER-COOLED SURFACE
Fraction Radiated of Net Heat Available in Pulverized-Coal-Fired Furnace
First Series, Manchester, England
Second Series, Manchester, England
Brighton, England
Hell Gate Power Plant, New York
Kip's Bay Steam Plant, New York
Net Heat Available per Hr. per Sq. Ft. of Water-Cooled Surface, 10,000 B.t.u.

Fig. 7—Ratio of heat radiated to net heat liberated and in preheated air.

ture by about 200 deg. fahr., a variation of 20 would affect the furnace-outlet temperature by less than 10 deg.

These data therefore indicate that the effectiveness factor is not affected by the CO_2 percentage. It would also seem reasonable to assume that the factor is not affected by the preheated-air temperature.

To illustrate the use of the effectiveness factor, we shall calculate the furnace-outlet temperature as affected by the preheated-air temperature for a typical Pittsburgh bituminous coal burned in a furnace having a volume of 8396 cu. ft. and having 3040 sq. ft. of water-cooled surface exposed to radiation, or 0.3620 sq. ft. per cu. ft. of furnace volume.

The composition of this coal as fired is: Moisture, 3.4 per cent; sulphur, 1.0 per cent; hydrogen, 4.7 per cent; carbon, 74.4 per cent; nitrogen, 1.4 per cent; oxygen, 6.7 per cent; ash, 8.4 per cent. Assuming 80 per cent of the ash to be flue dust containing 20 per cent combustible and practically no carbon in the

TABLE 4 — SENSIBLE HEATS OF GASES

Temperature, deg. fahr.	Heat added under constant pressure, B.t.u. per lb-mole CO_2	H_2O	N_2, O_2, CO (dry air)
0	0.0	0.0	0.0
32	278.0	265.4	222.6
60	524.5	497.8	417.5
70	613.3	580.8	487.2
100	882.0	830.0	696.1
200	1,801.6	1,661.9	1,393.6
300	2,756.9	2,496.6	2,092.6
400	3,745.8	3,335.1	2,793.5
500	4,766.4	4,178.0	3,496.5
600	5,816.6	5,026.3	4,201.7
700	6,894.7	5,880.8	4,909.5
800	7,999.0	6,742.3	5,620.1
900	9,127.6	7,611.8	6,333.6
1000	10,279.0	8,489.9	7,050.5
1100	11,451.6	9,377.7	7,770.9
1200	12,643.8	10,275.9	8,495.0
1300	13,854.3	11,185.4	9,223.0
1400	15,081.6	12,107.0	9,955.3
1500	16,324.4	13,041.6	10,692.1
1600	17,581.4	13,990.0	11,433.6
1700	18,851.6	14,953.0	12,180.0
1800	20,133.7	15,931.6	12,931.6
1900	21,426.6	16,926.5	13,688.6
2000	22,729.5	17,938.7	14,451.3
2100	24,041.4	18,968.8	15,219.9
2200	25,361.4	20,017.9	15,994.6
2300	26,688.7	21,086.7	16,775.7
2400	28,022.6	22,176.1	17,563.5
2500	29,362.4	23,287.0	18,358.1
2600	30,707.5	24,420.1	19,159.8
2700	32,057.4	25,576.3	19,968.8
2800	33,411.6	26,756.5	20,785.4
2900	34,769.7	27,961.5	21,609.9
3000	36,131.3	29,192.2	22,442.4

ashpit refuse comprising the remaining 20 per cent of the ash of the coal, the unburnt carbon will be 0.017 lb. per lb. of coal fired. The carbon burned will by 0.744—0.017 = 0.727 lb. per lb. of coal fired.

Hence, in the furnace exit gases will be 0.727/12 = 0.0606 mole of CO_2 and CO per lb. of coal fired. There will also be 0.010/32 = 0.0003 mole of SO_2 which will be treated as CO_2. With no CO and 15 per cent CO_2, there will be 0.0609/0.15 = 0.4060 mole of dry products, of which 0.4060 — 0.0609 = 0.3451 mole is O_2 and N_2. From the hydrogen in the coal there will be formed 0.047/2 = 0.0235 mole of H_2O. The moisture present in the coal is equal to 0.034/18 = 0.0019 mole of H_2O.

The dry air supplied for combustion equals the moles of dry products plus one-half the moles of H_2O formed from the hydrogen in the fuel minus the

number of moles equivalent to the nitrogen and oxygen in the fuel. The last mentioned are equal to 0.014/28 = 0.0005 mole of N_2 and 0.067/32 = 0.0021 mole of O_2, respectively. Hence, 0.4060 + 0.0118 — 0.0005 — 0.0021 = 0.4152 mole of dry air. For a relative humidity of 70 per cent at 70 deg. fahr., each mole of dry air has with it 0.0176 mole of water vapor, or 0.4152 × 0.0176 = 0.0073 mole of water vapor per pound of coal fired.

The air supplied for combustion per pound of coal fired thus consists of 0.4152 mole of dry air and 0.0073 mole of water vapor. The products of combustion leaving the furnace consist of 0.0609 mole of CO_2 (and SO_2), 0.3451 mole of O_2 and N_2, and 0.0235 + 0.0019 + 0.0073 = 0.0327 mole of H_2O. By means of Table 4, the sensible heat in the preheated air and in the products of combustion may be determined for any temperature desired.

Now, the gross heating value of this Pittsburgh coal is 13,700 B.t.u. per lb. The loss due to unburnt carbon is 0.017 × 14,600 = 248 B.t.u. The heat required to evaporate the moisture in the coal and that formed from the hydrogen is 1050 (0.047 × 9 + 0.034) = 480 B.t u. Hence, the net heat liberated is 13,700 — 248 — 480 = 12,972 B.t.u. per lb. of coal fired. Assuming 90 per cent of the air supplied for combustion to be preheated to 300 deg. fahr., we find the sensible heat above 70 deg, fahr. to be 610 B.t.u., making 12,973 + 610 = 13,583 B.t.u. for radiating and raising the temperature of the products of combustion.

For a gross heat liberation of 29,500 B.t u. per hr. per cu. ft. of furnace volume, we have 29,500/13,700 = 2.153 lb. of coal fired per hr. per cu. ft., or 2.153 × 0.3620 = 5.948 lb. per hr. per sq. ft. of water-cooled surface exposed to radiation.

By assuming various temperatures of the products of combustion leaving the furnace, a balance may be found in which the heat radiated per square foot with a factor of, say, 1500, divided by 5.948 lb. of coal fired per sq. ft., plus the sensible heat in the products of 1 lb. of coal, just equals 13,583 B.t.u. For the conditions assumed, this temperature is 1874 deg. fahr.

By similar calculations for other preheated-air temperatures, the following furnace-outlet temperatures are found to correspond to several effectiveness factors:

Effectiveness factor	1500	1000	500
Furnace-outlet temperature, deg. fahr.:			
70-deg. fahr. air	1837	2014	2325
For 300 deg. fahr. preheated air	1874	2057	2379
For 600 deg. fahr. preheated air	1922	2111	2446

The above furnace-outlet temperatures show an increase of somewhat less than 200 deg. fahr. for a change in the factor from 1500 to 1000, and a further increase of about 300 deg. fahr. for a change in the factor from 1000 to 500.

The heat absorbed by the water-cooled surfaces exposed to radiation in a furnace is somewhat less than the heat radiated from the burning fuel and products of combustion as calculated by this method, by reason of loss of heat from the furnace casing to surrounding objects. Also, the "unaccounted for" loss assumed as a margin of safety in a heat balance for a pulverized-coal-fired furnace, may be subtracted from the heat radiated as the most convenient place of including this item in an analysis of a steam-generating unit.

The "effectiveness factor" can be applied to stoker-fired furnaces as well as to pulverized-fuel furnaces, and also to oil- and gas-fired furnaces. By experimental and operating experience with furnaces of different types burning various fuels, judgment is developed in selecting the proper factor for determining the heat absorbed by radiation and the furnace-outlet temperature, either by calculation or from curves for typical fuels.

Author's Note—In discussing the above paper, Prof. Trinks said that it reminded him of the farmer who wanted to determine the weight of a mass of hay. So he carefully balanced the hay by a bucket of stones and then estimated the weight of the stones.

This is not only a good story but an excellent analogy; for the farmer undoubtedly had experience in determining the weights of stones so that his judgment had been developed in correctly estimating their weights. In such an instance, the weights of stones would obviously depend upon a less number of variables than the mass of hay.

As stated in the last paragraph of the above paper, judgment can be developed by experience in selecting the "effectiveness factor" for given furnace conditions, fuel characteristics and methods of firing. Thus, for a given carbon dioxide percentage, a given preheated air temperature and a given rate of firing per square foot of water-cooled surface, the furnace outlet temperature can be calculated by the method described and the rate of heat absorption by the water-cooled walls determined therefrom.

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U. G. I. Announces $31,000,000 Plan for 1931

In an announcement made December 26, John E. Zimmerman, President of the United Gas Improvement Company stated that subsidiary companies will spend $31,227,000 for additions and improvements to their properties in 1931.

Mr. Zimmerman said that projects included in the budget will be pushed forward as rapidly as possible in order to take advantage of present low costs of materials and to help relieve unemployment.

Chemical and Physical Reactions of Sodium Aluminate when used in Boiler Feed Water

By J. A. HOLMES, Director of Service
National Aluminate Corporation, Chicago, Ill.

As the title of this article implies, the author describes the physical properties and chemical characteristics of sodium aluminate when used in boiler feedwater. Its effect on silicate and methods of application are also discussed. In the conclusion emphasis is placed on the importance of using this material correctly. In this connection the author states that users should have either the company furnishing the material or their own chemist or engineers thoroughly check the treated boiler water to assure that all possible benefits are being obtained by the proper application of this valuable chemical.

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MORE interest in boiler feed water treatment has been in evidence the last few years than ever before due chiefly to the development of higher ratings and pressures. Consequently much research work has been done and many theories advanced dealing mostly, however, with high pressure or supplementary treatment after lime and soda plants with phosphates.

With the higher pressures (above 250 lb.) it is generally recognized that phosphates should be used and most research and operating engineers and chemists agree on this point. Differences in opinion rest mainly with the type of pretreatment of the feed water prior to phosphates or in the type of phosphates used and manner of feeding. High pressure plants deal with fairly low percentages of make-up, feed water of low incrusting solids (softened or evaporated), modern equipment, and in addition usually have the advantages of a chemical laboratory. Also, they are for the time being limited to only one possible chemical and method of control and operation.

However, there are still many plants operating at low pressure with high percentages of make-up and with water of wide variation in chemical consistency. Some of the plants operate successfully with water softeners, but many are left to the mercy of the old fashioned boiler compound chiefly because those most competent have confined their research work to high pressures.

It is true that the water softening equipment companies have done much educational work but not all plants can have softeners and must resort therefore to internal treatment. With these points in mind the following article is written, although the theories advanced apply to and in many instances are being used for high pressure work.

The two principal difficulties encountered in boiler feed work are carryover and scale formation. Carryover can usually be attributed mainly to physical conditions. Scale formation is the result of both chemical and physical conditions although the latter is usually disregarded. It is both for physical and chemical reasons that sodium aluminate is recommended for boiler feed treatment when used either internally or externally. To prevent confusion the use of sodium aluminate internally will be described first, followed by an explanation of its use in external water softening equipment.

Physical Properties (Internal)

Sodium aluminate is used internally (that is directly in the boiler) chiefly for its effect on suspended solids, or in other words as a coagulant. Coagulation for internal treatment is of advantage for two reasons. Carryover is effected more largely by the physical character, rather than the quantity, of suspended solids present in boiler water. Finely divided material is more conducive to foaming than flocculated or coarse particles, especially in the presence of high alkalinity or soda salts. The fine particles tend to collect in the surface of the steam bubbles and according to theory increase the surface tension of the bubbles. By coagulating these particles, the carryover tendencies of finely divided particles are eliminated. This feature permits the carrying of higher concentrations of alkalinity without foaming. Secondly, coagulated boiler sludge flows easily with the circulating water and does not settle out or bake on as scale. Scale that results from straight soda ash, caustic soda or phosphate treatment is usually the result of baking on of finely divided materials. One plant illustrating this point was using only sufficient tri-sodium phosphate on an 18 grain bicarbonate hardness water to obtain an excess soda alkalinity in the boiler water to average 15.0 grains (methyl orange alkalinity). By using 0.1 lb. of 32 per cent solution of sodium aluminate per 1,000 gal. of make-up, coagulation was obtained. Difficulty, previously experienced, from scale and burnt out tubes was eliminated. Analysis of the boiler water showed no change chemically, the only difference being in the physical characteristics of the boiler sludge by coagulation.

In the many installations using sodium aluminate never has the flocculent precipitate formed by sodium aluminate been objectionable due to settling out in quiet spots of the boiler as inferred by Mr. E. P. Price in his article in the January, 1930 issue of COMBUSTION. Aluminate is, on the contrary, used to prevent this occurrence as flocculated boiler sludge does not pack or bake on as quickly as uncoagulated sludge. It does not stick to the metal and even a slight movement of the water picks it up and carries it along with the water. This can be demonstrated by allowing a sample of coagulated and uncoagulated sludge to settle in sample bottles. The uncoagulated sludge will adhere to the bottom of the bottle but the coagulated sludge will never adhere, but will flow with the water even after long periods of settling.

Chemical Characteristics (Internal)

Sodium aluminate reacts directly on magnesium for the formation of magnesium aluminate, a flocculent precipitate. Calcium aluminate is fairly soluble and calcium is therefore not precipitated by sodium aluminate. In the presence of calcium or magnesium, sodium aluminate reacts on soluble silica for the formation of calcium or magnesium aluminum silicate which are also flocculent materials. In making analyses of a large number of scales it has been noted that some scales contain as high as 50 per cent silica or practically pure calcium and magnesium silicate. In order to prevent these silicate deposits a certain ratio must be maintained between the aluminate and silica in the boiler water. Experience has shown that by using sufficient sodium aluminate so that alumina in the boiler water is equal to or greater than the silica, the silica will be precipitated as flocculent matter and silica scale thus prevented. In some cases the calcium or magnesium content of the feed water may be lower than the silica or insufficient to form calcium or magnesium aluminum silicate. With these waters, good results have been obtained by using magnesium sulphate in conjunction with sodium aluminate in sufficient quantities to precipitate the silica. Also on soft waters a combination of phosphate and sodium aluminate gives excellent results. Phosphates are added to combine with the calcium, and sodium aluminate must be present in sufficient quantity to precipitate the silica and magnesium as magnesium aluminum silicate.

The following table shows soluble silica reduction when sodium aluminate is used.

TABLE I
SILICA CONTENT OF BOILER WATERS
GRAINS PER GALLON

	No. 1	No. 2	No. 3
Without aluminate.....	6.35	5.09	0.98
With aluminate.	1.05	1.78	0.03

Control (Internal)

Sodium aluminate treated water is controlled from both a physical and chemical standpoint. The initial dosage of aluminate is based on an amount necessary to coagulate the sludge that will be formed which is in direct proportion to the total hardness of the make-up water. Should the make-up water be classed as one high in silica the aluminate dosage is then based on the silica content. Coagulation is controlled by observation of the boiler water, the treatment being increased or decreased according to floc formation. To explain floc formation to the inexperienced, a non-coagulated sludge is compared to a fog and coagulated sludge to a snow storm. Upon sampling, a water properly treated with sodium aluminate will settle rapidly leaving a supernatant very clear water, with a loose, flocculent sludge that settles and flows easily.

Water that does not have sufficient sodium

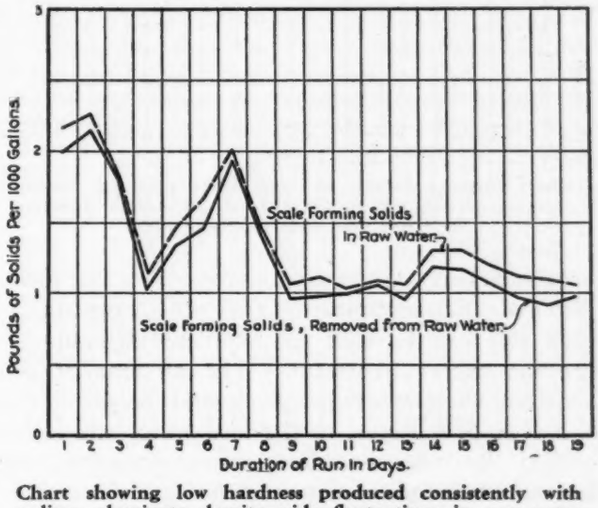

Pounds of Solids Per 1000 Gallons
0
1
2
3
Scale Forming Solids In Raw Water
Scale Forming Solids, Removed from Raw Water
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Duration of Run in Days.

Chart showing low hardness produced consistently with sodium aluminate despite wide fluctuations in raw water hardness.

aluminate for silica removal rarely shows coagulation, so that appearance of the boiler water aids in control for silica removal although complete analysis for silica should form the basis of control for silica scale prevention.

Besides the appearance of the boiler water hardness (usually by soap method) phenolphthalein and methyl orange alkalinities, chlorides and sulphates should be checked daily. Occasional total solids should also be determined as well as silica-alumina and alkalinity-sulphate (embrittlement) ratios. A boiler water of less than one grain total hardness and silica should be maintained at all times, accompanied with sufficient alkalinities to soften the water and thus prevent corrosion. Concentration of solids to prevent foaming should also be regulated by the routine tests.

The hardness, alkalinities, chlorides and sulphates can be determined by simple tests and require no chemical knowledge. Total solids, silica and

alumina must be determined gravimetrically and require chemical training. However, these tests need not be frequently made as, once the amount of sodium aluminate necessary for silica removal is known, only occasional checks need be made to determine any error due to variation in character of the make-up water.

The aluminate dosage necessary for floc formation or silica removal is seldom sufficient to remove hardness and give proper excesses of treatment. While complete softening can be obtained with aluminate a more economical treatment comprises the use of

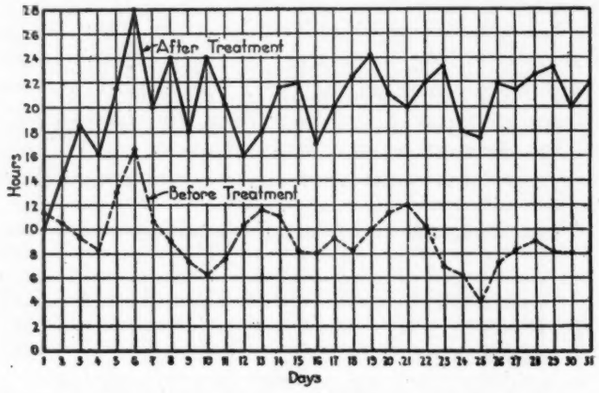


Chart showing length of time fillers operated between cleaning periods, before and after use of sodium aluminate in a hot lime soda softening plant.

only sufficient sodium aluminate to give floc formation and silica precipitation after which any alkaline soda salt can be used to complete softening and provide excess treatment. The amount of such auxiliary chemicals required, depends on the amount and type of hardness in the feed water and is controlled by the hardness, phenolphthalein and methyl orange alkalinity tests.

Physical Properties (External)

Sodium aluminate is used in conjunction with lime and soda ash in external treating plants for both physical and chemical reasons. Sodium aluminate is a very reactive chemical especially in the presence of magnesium. This permits the formation of floc very rapidly in the softener which floc acts as a nucleus for the lime and soda reactions. Rapid and complete floc formation insures complete chemical reactions, rapid settling in the softener, and a minimum of carryover of suspended solids to the filters. Proper coagulation and settling is recognized as a very necessary item in cold process softening. Some hot process lime and soda plants may operate without a coagulant but the use of sodium aluminate in these plants has proved of marked benefit. It increases the amount of settling in the main softener, improves filter operation, and is of special advantage in coagulating and filtering out finely divided or colloidal silica.

Another advantage of properly coagulated sludge with sodium aluminate results from the fact that a loose flocculent sludge flows more easily. On flat bottomed softening tanks this is of special advantage for efficient operation of the sludging system. A sludge that flows easily does not build up between the openings in the outlet pipes and permits a maximum removal of sludge with a minimum of waste of water.

Chemical Characteristics (External)

Chemists have been wont to compare the reactions of sodium aluminate with that of alum, which cannot be done. The aluminum in sodium aluminate is in the negative aluminate radical whereas in ordinary aluminum sulphate or filter alum the aluminum is itself the positive radical. Since one is positive and the other negative, the reactions differ greatly. The aluminum in aluminum sulphate tends to form aluminum hydrate as the coagulating medium whereas the aluminate ion must be broken down before the aluminum in the aluminate ion can form aluminum hydroxide.

When reacting with acids, bicarbonates or free carbon dioxide, sodium aluminate will hydrolize to form aluminum hydroxide and the corresponding salt of the other chemical present. In the case of water treatment, the sodium aluminate would react with the calcium bicarbonate to form calcium carbonate and aluminum hydroxide. However, in its reactions with magnesium salts, magnesium aluminate is formed which is a very flocculent precipitate and has all of the advantages of aluminum hydroxide as a coagulant. In addition to these advantages, magnesium aluminate is stable over wide ranges of pH especially the higher alkaline ranges, while aluminum hydroxide floc is dissolved at the higher pH values. Since all waters contain a small amount of magnesium, floc formation can therefore be maintained in highly alkaline waters. This is of special advantage in plants that must carry high overtreatment of lime and soda ash.

The effect of sodium aluminate chemical reactions and its floc formation upon residual hardness left in treated water is illustrated in table No. 2.

TABLE 2

Plant	Date	Hard.	Pht.	M.O.	Lime	Soda Ash		Coagulant
A	5-5-30	1.5	3.2	4.0	445	295	50	Iron sulphate
A	5-5-30	0.9	2.9	4.9	425	240	40	Sod. aluminate
B	8-14-29	3.2	4.3	5.7	53	10		None
B	8-15-29	1.7	3.3	4.2	53	5	10	Sod. aluminate

Tests in grains per gallon. Treatment in pounds per batch.

The softening value of sodium aluminate can be compared to caustic soda. Thus it replaces some lime and soda ash, while acid coagulants, alum and iron sulphate require additional alkaline chemicals for their reaction.

Effect on Silica

The use of sodium aluminate in external plants for silica reduction is of marked advantage especially

in hot process plants. It is just as impossible to completely eliminate silica with sodium aluminate as it is to entirely remove all calcium and magnesium salts, but a reduction in silica to an absolute minimum is desirable. This is accomplished by using sufficient sodium aluminate based on untreated, treated and boiler water analysis to insure a reduction of silica below the alumina content of the treated and boiler water. It is desirable to reduce silica to below 0.25 grains per gallon with the alumina at least equal to or greater than such amount. In the softener the reactions involve the formation of calcium or magnesium aluminum silicate which, being flocculent precipitates, not only reduce the silica content of the treated water, but aid coagulation as well. With the alumina in treated water higher than the silica, any silica that passes over into the boiler will then precipitate out as a calcium or magnesium aluminum silicate, a non-adhering and non-scale forming material. If the aluminum is less than the silica, some of the silica will precipitate out as calcium silicate, a scale forming material.

Silica treatment is controlled by regular analysis of both the treated and boiler water. The treated water should show, as stated before, a higher alumina than silica content. This should carry through into the boilers so that boiler water analysis indicates an alumina content higher than the silica.

Table 3 shows the effect of aluminate treatment on silica reduction in actual softening plant operation. The sodium aluminate column shows treatment in grains (dry basis) used per gallon. The other tests are also expressed in grains per gallon. The lime and soda ash treatment was calculated to give the same amount of overtreatment in each case.

TABLE 3

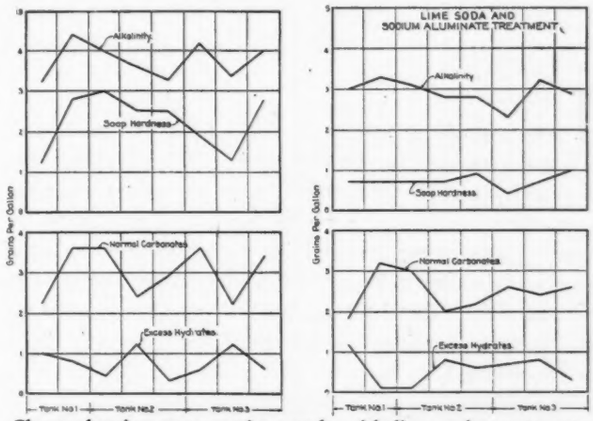
Sample	Sodium Aluminate	Silica	Alumina
1	0	0.39	0.1
2	0.4	0.29	0.07
3	0.58	0.22	0.02
4	1.1	0.16	0.44
5	1.1	0.2	0.34
6	1.1	0.18	0.44

Applications

In intermittent water softeners, the sodium aluminate is usually added after the lime and soda ash or with the soda ash. In continuous softeners, the sodium aluminate except in very rare cases, is added directly with the lime and soda ash mixture. If the soda ash treatment in pounds is in excess of the lime so that practically all of the lime is converted to sodium hydroxide then the sodium aluminate remains as sodium aluminate in the chemical tank. If the lime in the chemical tank is in excess of soda ash so that some free lime remains as such, some of the sodium aluminate will be converted to calcium aluminate. This is of no disadvantage, however, as calcium aluminate formed in this manner, if not allowed to dry, is in reactive form, soluble and will produce the aluminate reactions desired in the softener. This feature has marked advantages over acid coagulants which must be fed separately.

Conclusions

The use of sodium aluminate either internally or externally is dependent, as is any other chemical or chemical process, upon definite control. Too many are prone to use sodium aluminate as a boiler compound or merely as a coagulant in a water softening plant. Its use should be accompanied by service of a company or consulting engineer who is familiar with the possibilities of the material and the proper method of control of dosages, etc. To use sodium aluminate merely as a coagulant without the accompanying check on silica removal, proper coagulation, settling, filter operation, etc., is to fail to secure the maximum benefits possible. Any user of sodium aluminate should not be content with the mere fact that they are obtaining coagulation and settling in an external plant or good coagulation when using the material directly in the boiler, but should insist that either the company furnishing the material, or their own chemist or engineer, thoroughly check the treated boiler water so as to



Charts showing comparative results with lime soda treatment (charts on left) and lime soda and sodium aluminate treatment (charts on right).

ascertain that maximum benefits are being obtained by the proper application of this very valuable chemical.

The fact that sodium aluminate requires rigid control, eliminates its use as a common "cure-all." Promiscuous application of sodium aluminate in boiler or softening plant will seldom produce better results than the old boiler compound method. However, by taking full advantage of the peculiar chemical reactions of sodium aluminate, and by applying them to the treatment of water, improved results will be obtained which are sure to return large dividends to any properly operated power plant.

Fifth Boiler Unit Now in

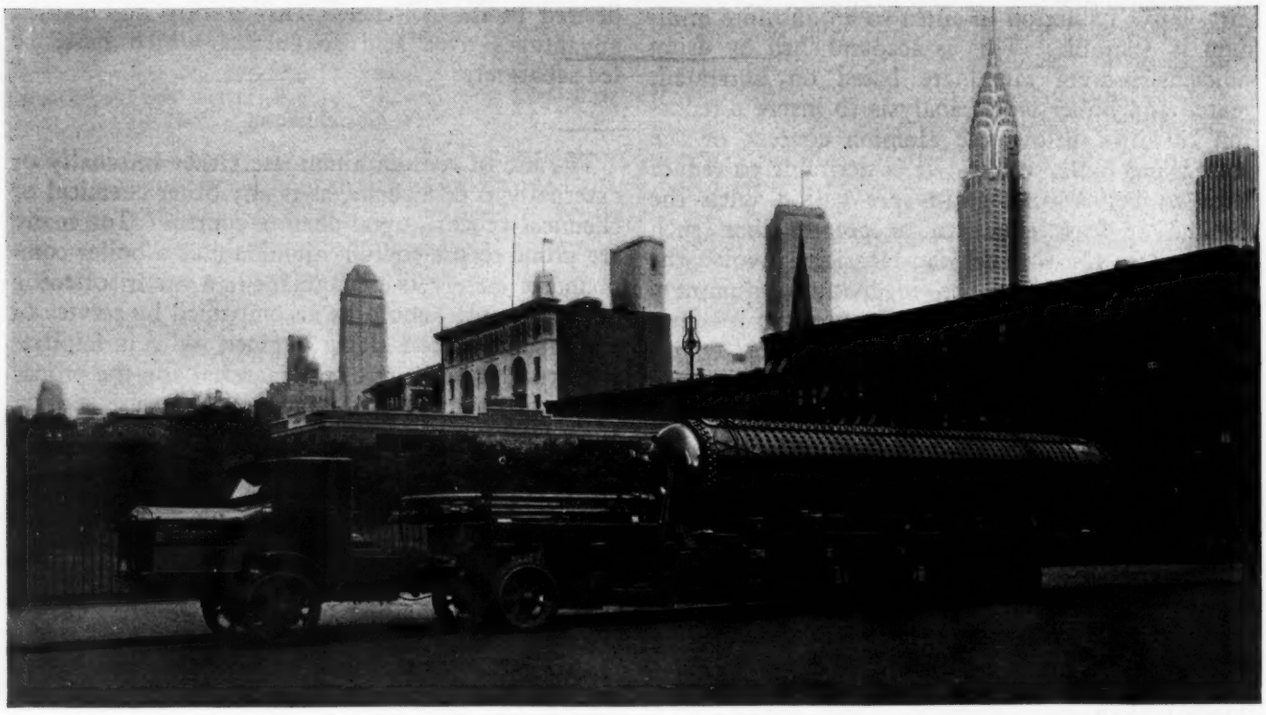


Fig. 1—One of the drums for the fifth unit being delivered to Kips Bay. In the background are the Chrysler building and other New York skyscrapers served by the New York Steam Corporation.

THE rapid growth of the New York Steam Corporation and particularly of its Kips Bay Station, is readily understood when one considers that five new office buildings, ranging from fifty to eighty-five stories, are being erected in a comparatively small area within one-half mile of the Kips Bay Plant. One of these, the Empire State building, when completed will alone require in excess of 125,000,000 lb. of steam a year.

In 1926, after an extensive study of existing plants, the engineers of the New York Steam Corporation decided to use pulverized fuel in their new Kips Bay Station to be located on the East River at 35th St.

Designs were completed and a building was erected to accommodate six steam generating units. In that year, three complete generating units were installed and the following year a fourth unit was placed in operation. Despite the large capacity of the four existing units, it became evident in 1929 that the rapidly growing heating load of the Grand Central Zone would shortly overtax the maximum station output. Accordingly, plans were made to install a fifth unit. On the 13th of March, 1930, the contract for the furnishing and installation of this unit was awarded to the Combustion Engineering Corporation which company had designed, manufactured and installed the four preceding units.

This unit, with a guaranteed continuous capacity of 700,000 lb. of steam per hr., is the largest unit used for generating steam for heating purposes and has been designed to occupy all available space in the fifth bay of the present building. The floor space occupied by the unit proper exclusive of secondary air ducts, measures 29 ft. x 40 ft. In height the unit, including forced and induced draft fans, will occupy the entire space between basement floor and building roof, a distance of 145 ft. 6 in., which is equivalent to a 12 story building.

As in the case of the four previous units, steam from the new unit was required the same year as the contract was let in order to take care of the winter load. Design work was started in the middle of March and the first drum arrived on the job June 20. On November 15, the date on which the unit was scheduled for operation, a fire was started and steam delivered to the line. On November 28 the unit was placed on the line for continuous operation, having been down for the previous two weeks in order to allow other contractors to finish their work.

The results thus far obtained indicate that the unit has been designed conservatively and will readily carry a continuous load of 750,000 lb. of steam per hr. Substantially higher peak loads can be carried when necessary as indicated by the steam flow chart,

Operation at Kips Bay Station of New York Steam Corporation

By A. R. LUDT

Combustion Engineering Corporation, New York

The Kips Bay Station of the New York Steam Corporation is in many respects one of the most interesting steam plants in the country. It was built in 1926 to serve the rapidly growing heating requirements of New York's Grand Central Zone and sections immediately adjacent to this area. The initial installation comprised three pulverized fuel fired boilers, each designed for a capacity of 325,000 lb. of steam per hr. The following year a fourth unit was installed which, although designed for a capacity of 375,000 lb. of steam per hr., has actually produced 450,000 lb. of steam per hr. as an average evaporation during the heating season. Now, only four years from the time of the initial installation, a fifth unit has been installed and placed in operation. This unit is guaranteed to produce 700,000 lb. of steam per hr. and has already evidenced its ability to carry loads in excess of this amount.

It may be said that the Kips Bay Station exemplifies, perhaps more so than any other plant in this country or abroad, the progress of the past five years in the design of complete steam generating units. It may also be said that this plant represents a concentration of steam generating capacity per square foot of ground area that is not exceeded by any other plant in the world, with the possible exception of the new section of the East River Station of the New York Edison Company.

Finally, the Kips Bay Station evidences as does no other plant the remarkable growth in the practice of centralized steam heating.

Fig. 3, showing a maximum production of over 1,000,000 lb. per hr.

The general layout of the unit is shown in Fig. 2. The principal details, size, capacity, etc., are as follows:

Design pressure	300 lb.
Operating pressure	285 lb.
Boiler heating surface	32,260 sq. ft.
Water wall heating surface (exposed)	8,250 sq. ft.
Economizer (2 economizer sections)	19,656 sq. ft.
Air preheater (2 air preheater sections)	61,440 sq. ft.
Furnace Volume	32,000 cu. ft.
Heat liberation per cu. ft. of furnace volume	26,200 B.t.u.
Maximum guaranteed steam output per hr.	700,000 lb.
Feed water temperature entering economizer	200 deg. fahr.
Feed water temperature leaving economizer	303 deg. fahr.
Gas temperature entering economizer	880 deg. fahr.
Gas temperature leaving economizer	521 deg. fahr.
Air entering preheater	100 deg. fahr.
Air leaving preheater	367 deg. fahr.
Gas entering preheater	521 deg. fahr.
Gas leaving preheater	336 deg. fahr.
Combined efficiency	85.5 per cent

The coal to be used is Pittsburgh or West Virginia running about 13,000 B.t.u. (dry basis) with ash fusion point of 2250 to 2480 deg. fahr. and with proximate analysis as follows:

Fixed carbon	54-65 per cent
Volatile matter	29-36 per cent
Ash	6-10 per cent
Moisture	6-10 per cent
Sulphur	1- 2 per cent

Boiler

The centerline of the dry steam drum is located 85 ft. 9 in. above the basement floor. This drum is 48 in. inside dia., 1-5/16 in. thick and the length overall is 33 ft. 4 in. On this drum are located six 8 in. safety valve nozzles with triple manifolds for mounting eighteen 4 in. Crosby safety valves, also four 12 in. steam outlet nozzles. Deflecting baffles are located in front of the steam circulating connection, also dry pipes at each steam outlet. The bottom of this drum is provided with 4 in. drain connections to a manifold header, located underneath the dry drum. The drain pipes from this header are so arranged that they discharge into the 36 in. dia. water screen supply drum located at the bottom of the furnace.

Two 60 in. inside dia. steam and water drums, spaced 15 ft. 4 in. apart, are located 13 ft. 9 in. below the centerline of dry steam drum. These drums are 2 in. thick and the length over heads is 33 ft. 2 in. In each head of these drums there is located a 6 in. feed nozzle and 1½ in. connections for Reliance water column equipped with Ernst inclined water gage. A

submerged feed distributing pipe and feed pan are provided in each of these drums. Horizontal perforated baffles similar to those installed in the previous units have been provided.

Two 54 in. inside dia. mud drums spaced 21 ft. 6 in. apart are located 24 ft. below the center of the upper

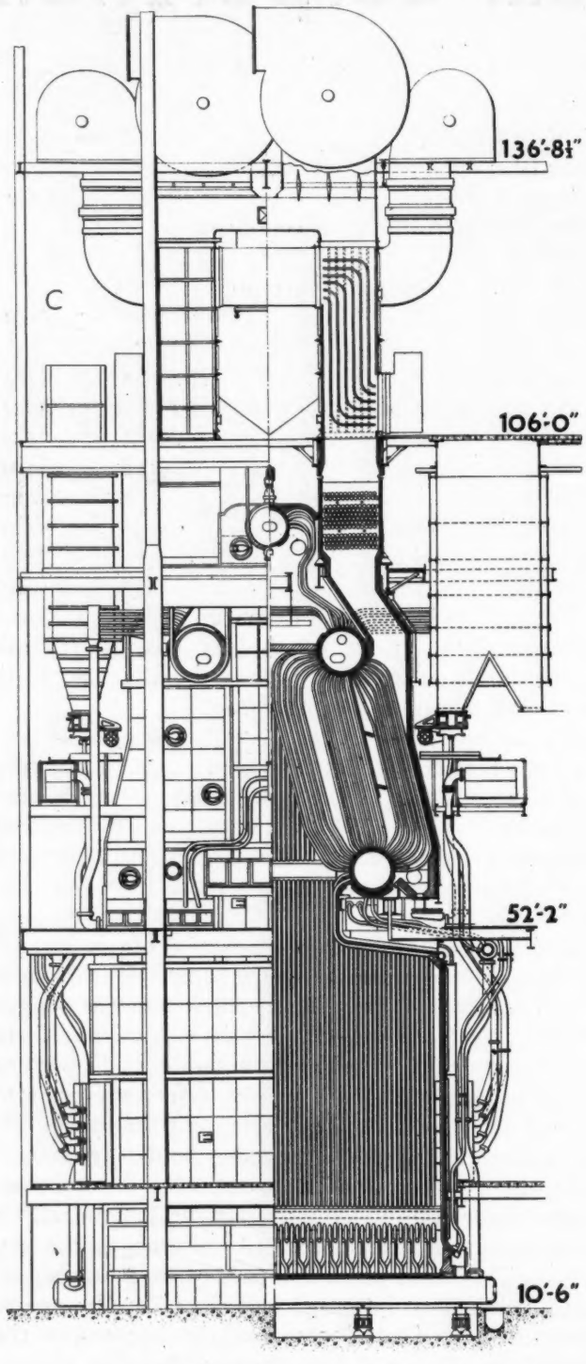


Fig. 2—Sectional elevation through fifth unit.

60 in. drums. These drums are 1-7/16 in. thick and the length over heads is 28 ft. 8 in. Water to all wall tubes is supplied from these drums by means of 4 in. tube connections located at the bottom of the drums. Three 2½ in. blow-off nozzles with piping and Yarway tandem valves are provided.

Boiler tubes are 3¼ in. dia., No. 9 B.w.g. and are arranged in two groups of three banks each. There are 43 tubes across the width of the boiler and, with the exception of those in the first two rows of each front bank, they are spaced on 7 in. centers. The boiler width at the tubes is 25 ft. Circulating tubes, 3¼ in. dia., connect the 60 in. drums with the 48 in. dia. dry drum. The steam drum is hung from overhead steel. The boiler proper is supported from overhead steel by means of U hangers fitted to the underside of the 60 in. drums at each end. Stops are provided on the 54 in. drum heads.

Water Walls

With the exception of the four corners, the entire wall surface of the furnace is faced with bare metal consisting of 4 in. dia. No. 6 gage tubes spaced on 6⅛ in. centers. The distance between faces of water wall tubes, front to back is 35 ft. 10 in., and the width 25 ft. 2 in. The furnace entrance to the boiler is formed by arch tubes connected on the lower end to the upper front wall headers and the upper end to the lower boiler drum. These tubes are spaced on 6⅛ in. centers. The water cooled surface in the furnace bottom consists of a triple depth hearth screen and a 36 in. inside dia., hammer-welded drum, 1¼ in. thick and 46 ft. 6 in. long over drum shell. With the exception of ten 4 in. dia. downtakes to each of the front and rear lower water-wall headers, all the water obtained from the lower boiler drums is fed into this drum for circulation through the water walls.

The triple depth hearth screen, which forms a water cooled surface over the shallow ash pit, consists of rows of 4 in. dia. tubes spaced on 21 in. centers. The vertical distance between each parallel row of tubes is 12 in. The rows are so staggered that there is a horizontal offset of 10½ in. between the intermediate rows. Where the tubes enter the 36 in. dia. supply drum, offsets are provided in the tubes to give a maximum amount of clearance for the passage of ash into the hopper bottom.

That part of the boiler side wall comprising the surface exposed to radiant heat has been covered with water cooled surface consisting of 4 in. dia., No. 6 gage, tubes spaced on 6⅛ in. centers similar to those installed on the furnace walls. The bottom ends of these tubes have been connected to an intermediate header to which is also connected the upper ends of the center side wall furnace tubes, as shown in Fig. 5. The upper end of boiler side wall screen is connected to a distributing header. From this header, 4 in. riser tubes are carried to the upper half of the 60 in. dia. boiler drums.

Water-Wall Circulation

Water, for the center sections of furnace side walls and for the boiler water-wall tubes, is supplied from the lower boiler drums and distributed through the 36 in. dia. supply drum to the hearth screen and the lower side wall distributing header. It then passes

up through the side wall furnace tubes, through the intermediate distributing header and boiler side wall tubes into the upper distributing header and finally through the riser tubes into the upper 60 in. dia. drum. The vertical distance between centerlines of the 36 in. dia. supply drum and of the upper side wall discharge header is 74 ft. 3 in.

For front and rear sections of the furnace side wall, the circulation is similar to the center portion with the exception that the upper ends discharge into collecting headers located 6 ft. below the lower boiler drums. A 12 in. dia. riser connection is carried from one end of each header to a vertical junction header; from this header, 4 in. dia. circulating tubes are carried horizontally into the upper 60 in. dia. drums.

For the front and rear wall furnace tubes, water is supplied to each lower distributing header partly by six 4 in. tube connections from the 36 in. dia. supply drum and partly by ten 4 in. tube connections from the lower boiler drums and is carried up through the furnace and arch tubes to the boiler mud drums. Internal circulators in these drums join the arch tubes with corresponding boiler tubes located in the rear of the first pass, thus providing a continuous passage to the upper 60 in. boiler drums. Blow-off connections (1½ in.) with Yarway tandem valves are provided on the lower front and rear wall headers and supply drum.

Insulation and Casing

The water walls are backed up with a wall section consisting of 2½ in. thick refractory tile, 3 in. thick rock wool panels and No. 12 B.w.g. flanged steel casing. The rock wool is compressed to 2½ in. when placing the casing into position.

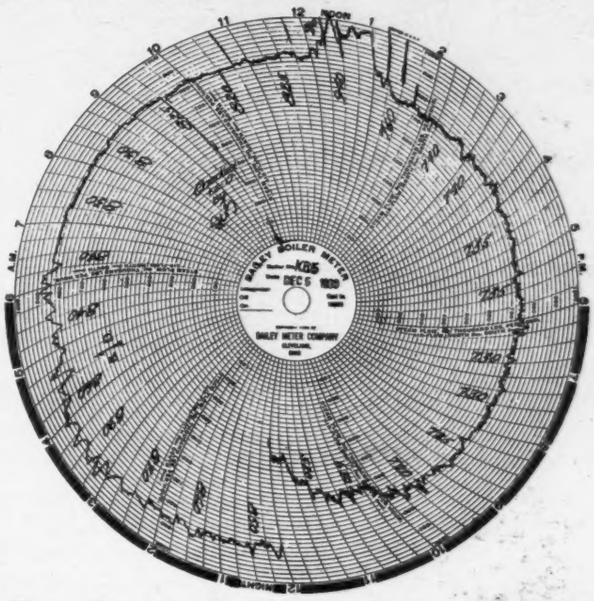


Fig. 3—Steam flow chart for December 5, 1930, showing peak production in excess of 1,000,000 lb. per hr.

Horizontal steel tie bands extending around the furnace are provided at the bottom, center and top. Each pair of water wall tubes is held to these bands by means of a tee welded to the tube and a cast iron tee section bolted to the band. In addition to the above every sixth tube is held to the flanged casing by means of short lugs welded at intervals along the length of the tubes and bolted to the casing. All of the tees are so designed that tubes can be removed

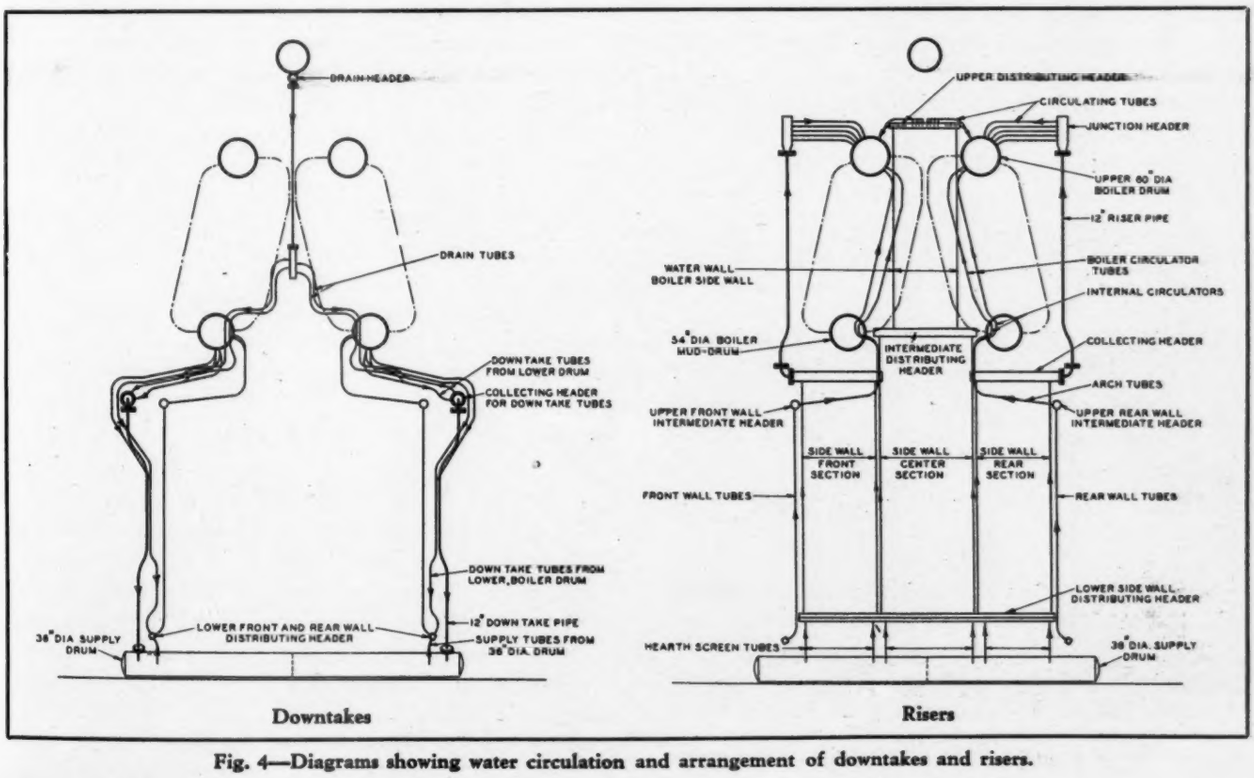


Fig. 4—Diagrams showing water circulation and arrangement of downtakes and risers.

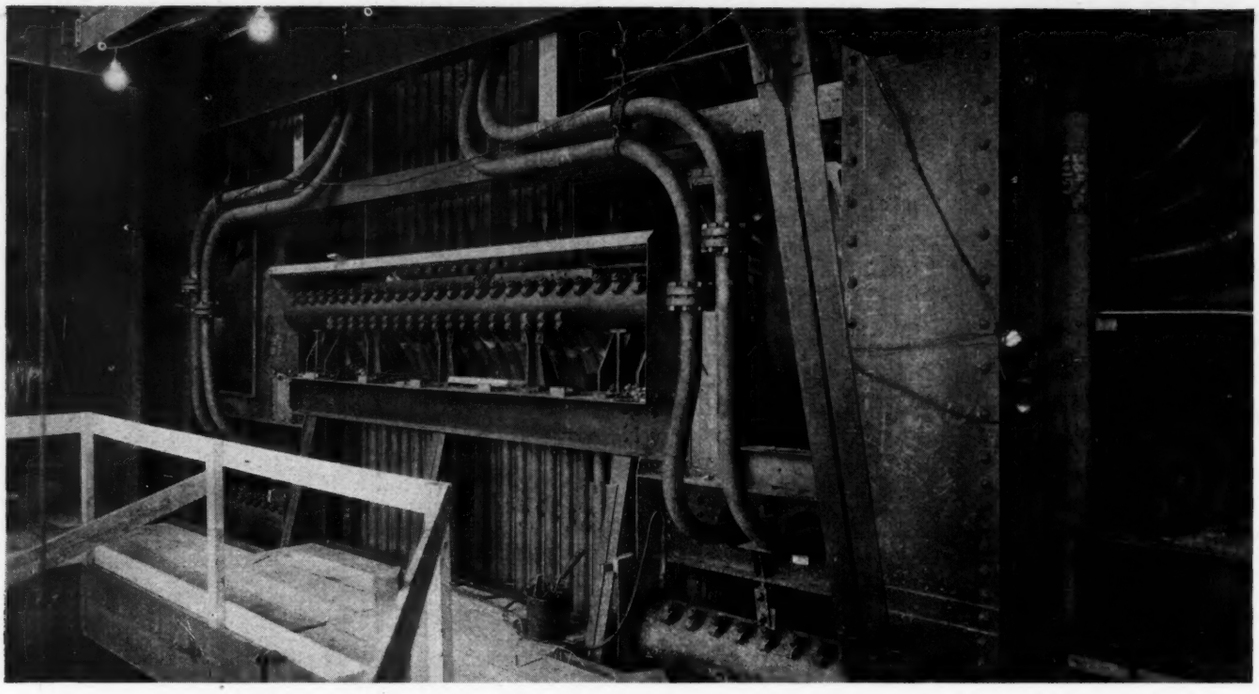


Fig. 5—View showing intermediate side wall header connecting upper side wall tubes with furnace side wall tubes.

from the inside of the furnace without removing any of the steel casing panels which are bolted to the horizontal ties and corner buckstays. Provision is also made for the vertical expansion of the tubes and the linear expansion of the water wall headers. All headers are covered with removable steel panels for access to hand hole fittings. The four corners of the furnace above and below the tangential burners consist of refractory tile held to the corner buckstays by means of holding castings. The portions of the boiler side walls, not water cooled, consist of 13½ in. fire brick, 2½ in. insulating brick and a flanged casing made of No. 10 B.w.g. steel plate. Rows of holding tile attached to horizontal casing bars by means of castings are provided at intervals in this wall.

The front and rear walls of the boiler consist of 2½ in. refractory tile at the tubes backed up with 3 in. rock wool and No. 10 gage flanged steel casing reinforced with channel buckstays. The flue necks and that portion of the front and rear boiler walls not in contact with the boiler tubes, consist of No. 12 Hi-Temp blocks held to the steel casing by means of plate washers and studs welded to the steel casing. The Hi-Temp blocks are covered with a ¾ in. thick coating of Vitrocel cement troweled smooth.

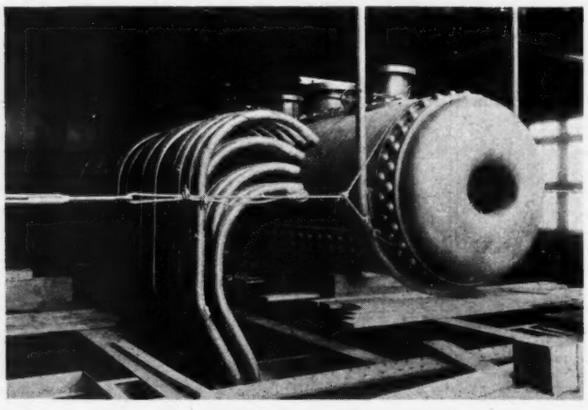


Fig. 6—View of dry steam drum showing method of support.

The lower drum heads are covered with an insulated casing and doors are provided for access to the manholes. The lower exposed surface of this drum is also insulated and steel cased.

A suspended arch between the two upper 60 in. drums forms the roof of the boiler proper. This arch is covered with 1 in. plastic material to insure tightness. The compartment between the upper 60 in. dia. drums and 48 in. dry steam drum is completely incased and insulated on the inside.

Thus the entire furnace and boiler surface with the exception of upper boiler and dry drum ends is covered with a steel casing.

Suitable doors are provided in the furnace and boiler for access and observation.

A dust hopper with four openings is provided at the rear of each lower boiler drum. Dust is removed by means of a Hydrovac dust system.

Ash Hopper

In order to obtain the maximum amount of furnace volume, a specially constructed ash hopper was installed. This hopper consists of seven troughs on each side of the furnace divided in the center by the 36 in. dia. supply drum. A dense, non-vitreous fire brick with low porosity has been used to form the troughs. Hollow tile has been placed on top of the concrete mat to allow for circulation of air to dis-

sipate the heat. Ash is removed by back-washing similar to hydraulic mining. The washed material passes through counter-poised gates located in the lower side walls. These gates are enclosed in a dust-tight compartment in which grid bars are located, through which the ash drops into the station's Hydrojet system. Observations made so far indicate that the triple-depth hearth screen provides a zone sufficiently cool to prevent the ash from fusing in the troughs. When operating at a continuous rating of 750,000 lb. of steam per hr., indications are that ash removal at intervals of 48 hr. will be satisfactory.

Fig. 7—Upper boiler drums and circulators leading to dry drum shown in Fig. 6.

Pulverized Coal Equipment

Referring to Fig. 2, pulverized coal is delivered to storage bins located on the north and south side of the unit. Four feeders with separate shut-off gates are attached to the bottom of each storage bin. These feeders are of the slow-speed, rotary, pocket type equipped with agitators and two coal inlets and outlets which measure the coal independently to two different burners. Flooding is prevented by adjustable clearance above and below rotor and choking is prevented by passing air through the feeder body with the coal. Each feeder is driven through chain and sprockets by a variable speed ¾ to 2 hp., 500-2000 r.p.m., d.c., Type CD, totally enclosed motor mounted on a bracket attached to the body of the shut-off gates. A venturi type mixer is located below each outlet from the feeder; at this point, the pulverized coal is brought into contact with primary air and carried through an 8 in. pipe to the tangential burner nozzles. A damper is provided at the primary air inlet to the venturi. Primary air is supplied by two Sturtevant Type SC No. 1 fans capable of delivering 22,000 c.f.m. at 150 deg. fahr. against 16 in. static pressure connected to a 100 hp. 1800 r.p.m. motor.

At the north and south ends of the unit, the primary air supply ducts are partitioned to form a supply header for the four feeders. A regulating damper is provided at the entrance to this header for controlling the amount of primary air to the group of four feeders. The primary air fans are inter-connected with the various units by means of tie connections to the main supply ducts. Hot air connections from the secondary air ducts are attached to the primary air fan inlets; a cold air tempering device is provided in this connection for controlling the temperature of the air leaving the fan which will be approximately 350 deg. fahr.

Tangential burners are located in the four corners

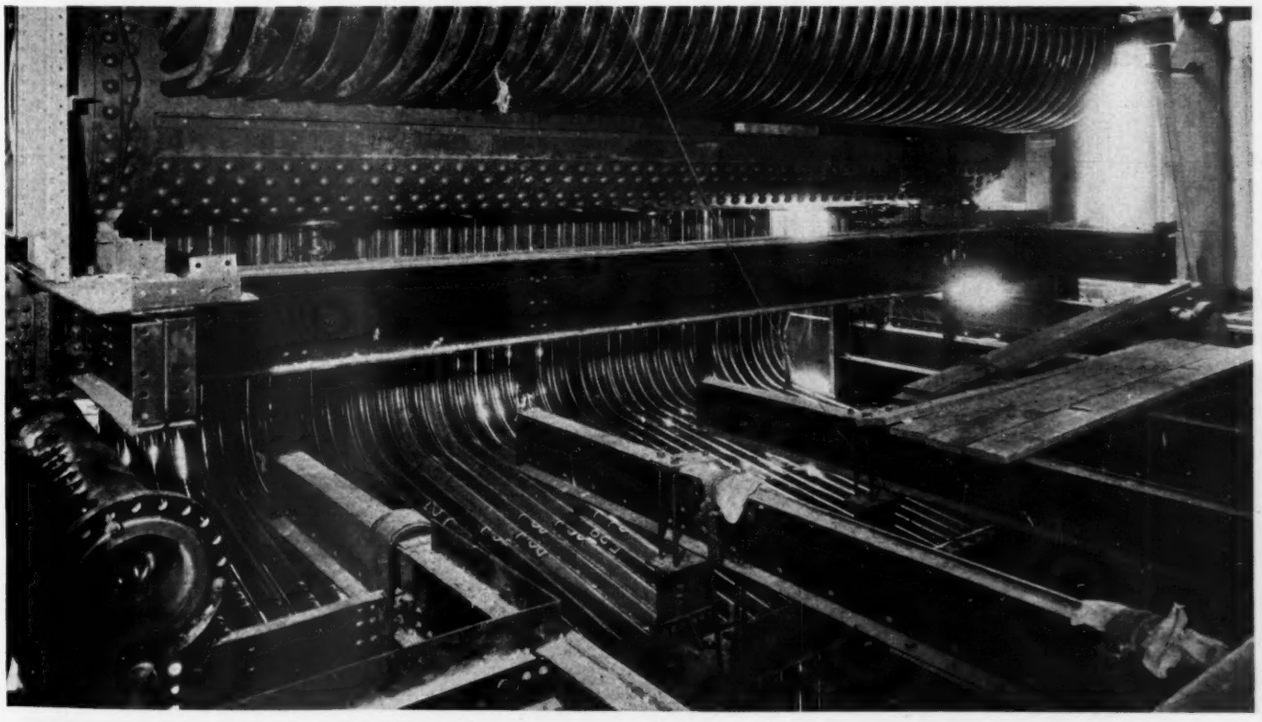


Fig. 8—One of lower boiler drums, arch screen and upper front wall header.

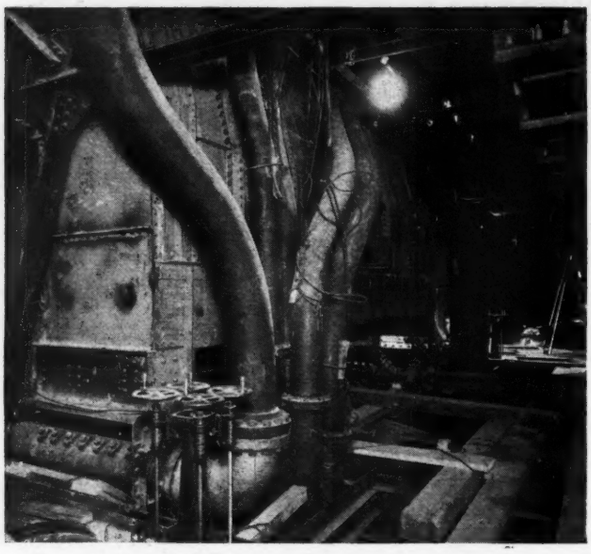


Fig. 9—View showing 12 in. sidewall riser and fuel feed pipes supplying tangential burners.

of the furnace, a clear opening of 15 in. being provided between the water screen tubes to accommodate these burners. The housing for the burners is made of steel plate 11 ft. 8 in. high and is divided into six compartments. The top and bottom compartments are used exclusively for secondary air and the four intermediate compartments house the cast iron burner nozzles. Dampers are provided in each compartment for regulating the amount of secondary air. These dampers are controlled from a stand located on the operating floor above. Adjustable cast iron deflector side plates are provided in each compartment at the entrance to the furnace. The cast iron fuel nozzles, which are provided with replaceable tips, are so centered that streams of the mixture of coal and primary air are directed towards the center, tangent to a 6 ft. dia. circle (see Fig. 10). Secondary air is supplied under pressure around the fuel nozzle and in the same general direction as the mixture of fuel and primary air. This produces a rotative motion which persists through a large portion of the furnace. A very intensive mixing is produced by the impingement of the streams against each other where they meet near the center of the furnace which makes it possible to obtain the high rates of combustion required to generate 750,000 or more pounds of steam per hour.

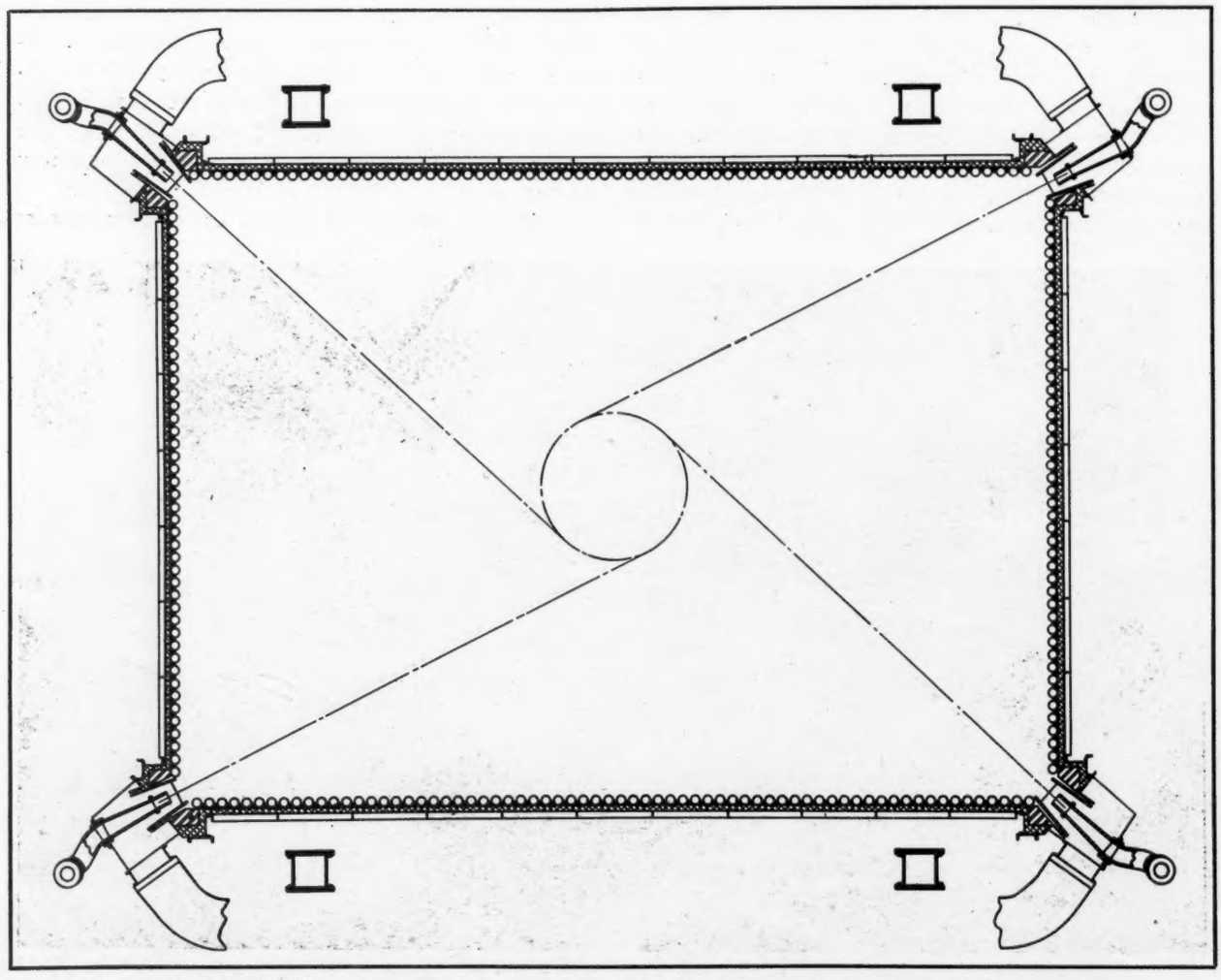


Fig. 10—Horizontal section through furnace at burner level showing arrangement of burners for corner firing.

Economizers, Preheaters and Fans

The hot gases after passing over the first banks of the boiler tubes separate into two streams and flow downward through the second passes and up through the third passes where they leave the boiler and enter the Foster Wheeler Economizers. After leaving the economizers, the gases pass through C-E plate type preheaters and enter a common induced draft intake chamber located directly above the preheaters.

Two American Blower induced draft fans discharge the gases into a Cottrell Precipitator located on the roof. Each fan is rated at 250,000 c.f.m. at a temperature of 395 deg. fahr. and 16.5 in. static pressure, requiring 1073 hp. at a speed of 583 r.p.m., and is driven by 600 r.p.m., 1100 hp. motors.

Two American Blower Company high speed forced draft fans supply the secondary air. Each fan has a capacity of 125,000 c.f.m. at 100 deg. fahr., and 12.5 in. static pressure. At this load, the speed is 865 r.p.m. and the horsepower 362. Each fan is driven by a 400 hp., 900 r.p.m. wound-rotor motor.

The secondary air is delivered to the preheaters where it follows S shaped passages through the heater elements. It is then distributed through ducts to the tangential burners located at the four corners of the furnace.

Regulation

Two 8 in. Copes feed water regulators with tension thermostats are installed. In order to take care of an excess pressure of 100 lb., valves are equipped with hydraulic relays.

Hagan Regulation will be installed on this unit. Variations in steam pressure will be used to vary the position of a damper in the discharge from the induced draft fans and, as this damper reaches its limit, the automatic regulator will change the fan speed, returning the damper to control position. The changes in the speed of the induced draft fan change the pressure drop through the economizers and the losses through the two economizers are totalized and used to vary the position of the gang rheostat controlling the speed of the coal feeders. Furnace draft is controlled by dampers in the forced draft ducts which in turn change the fan speeds when the dampers reach the limiting setting. Provision is made at the panel for varying the flow of air individually in the two forced draft ducts. Control is also provided to vary the furnace suction as well as the air fuel ratio. The control panel permits operating the unit under automatic control but at a higher or lower rating than the plant as a whole or permits operation at any rating that may be set under manual control.

Fig. 11—Preheated air is supplied by the two air preheaters shown in this view.

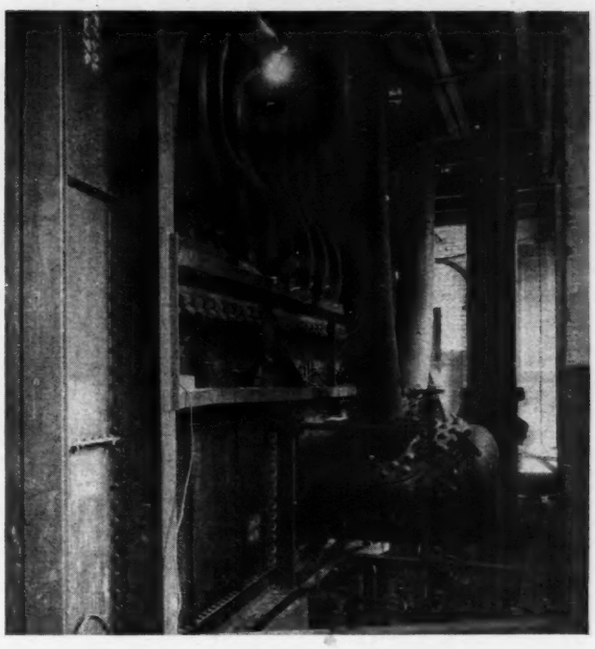


Fig. 12—Partial view of front wall showing water connection to 36 in. hearth screen drum and downtake connections to lower front wall supply header.

Panels are laid out so that the operator can throw the unit from full automatic to partial automatic or full manual as desired.

It is expected that this control installation will provide data on which the value of automatic control in a high load factor, comparatively evenly-loaded station, may be determined.

At present there are three 3,000 kw. generators in the station. A fourth 4,000 kw. generator will be added, making a total of 13,000 kw. The new generator will provide a stand-by unit. These generators supply power to all the auxiliaries which, with the exception of the feed pumps, are motor-driven.

Steam from all five units is generated at 285 lb. gage pressure and passed through throttling and Globe valves which reduce the pressure to a maximum of 165 lb. Four 20 in. dia. steam mains carry the steam from the station. These mains have a capacity of 2,400,000 lb. of steam per hr. which, for the present represents the maximum load the station can carry.

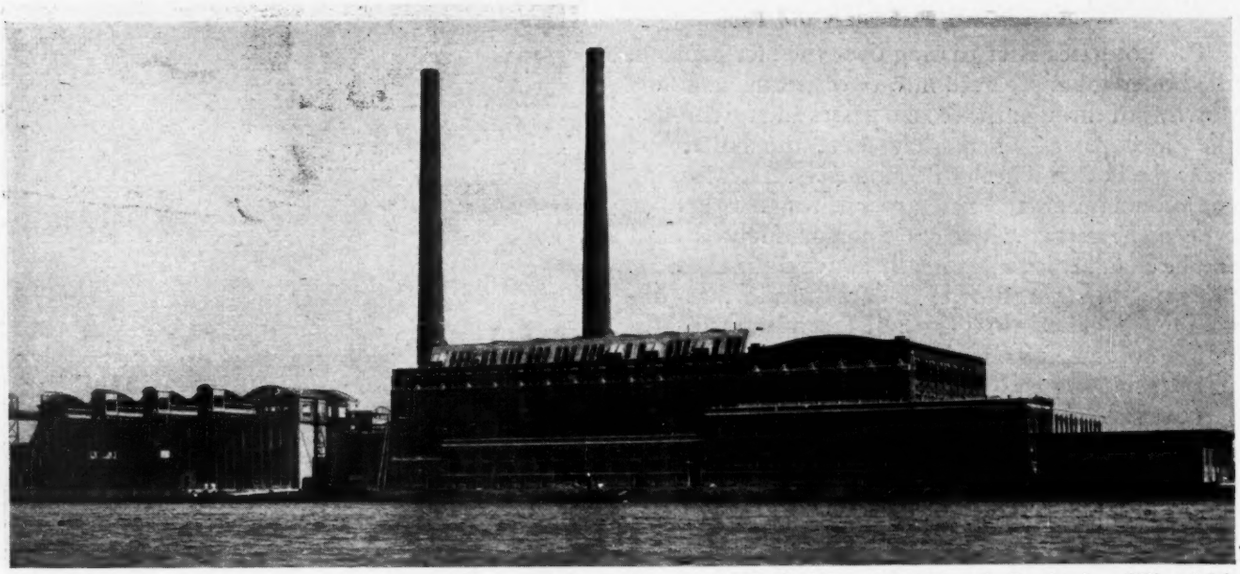


Fig. 1—Schelle Station of the Société Generale Belge de Production d'Electricité.

Modern Power Practice in Belgium

A Description of the new Schelle Station of Société Generale Belge de Productiond'Electricité.

By
DAVID BROWNLIE
L O N D O N

Progress in Power Generation is moving at a rapid pace in Belgium which has been one of the centers of major industrial advancement for centuries past, especially in connection with the technique of iron and steel production. Mr. Brownlie describes in detail the new Schelle Power Station, the first section of which was placed in operation in November 1930. This station is designed for an ultimate capacity of 500,000 kw., of which 90,000 kw. is now available from the section just completed. The author also discusses other notable power stations in Belgium which exemplify modern practice.

ONE of the most advanced countries in fuel technology is Belgium, whose history in this connection goes back to before the time of the Romans, as represented by the smelting of iron in very small intermittent clay furnaces, using charcoal, and hand or animal-operated bellows, and later, water wheels.

For many centuries, Belgium has been one of the chief iron-producing centers of the world. So far as can be ascertained, the smelting of iron ore was first accomplished about 3000 years ago in the Caucasus and Southern Russian area of Europe, especially in the neighborhood of the Caspian Sea and the Black Sea, by various tribes termed Scythians by the Romans. From this area, the knowledge of iron-making spread to the Hittites, Assyrians, and other races in the Near East, and eventually to the Egyptians, (probably about 800 B.C.), the Cretans, and the Etruscans, from whom the Romans derived so much of their knowledge. Also it penetrated to the Far East, and especially India, where the iron industry flourished in amazing fashion.

In general, the knowledge of how to smelt iron ores and make both iron and a crude form of steel, seems to have been carried into Europe by invading tribes following the great rivers, such as the Danube and the Rhine, by way of Roumania, Jugo-Slavia, Hungary, Austria, Syria, and Bavaria, eventually reaching Belgium, France, the rest of Germany, Spain, Scandinavia, and Great Britain.

For some reason not altogether clear, the Low Countries, that is now Belgium and Holland, became the most important iron-producing center in Europe, and it was in this area, for example, that as early as the reign of Charlemagne (A.D. 742-814) there was invented the "Furneau-a-Masse" or "Stückofen", being an improved iron smelting furnace, somewhat higher than the ordinary small clay furnace but still intermittent and therefore not a true blast furnace, the resulting mass of iron being extracted by breaking up the furnace. Eventually, however, there was invented at Namur in Belgium, about 1340, the modern blast furnace, that is the "Hautfourneau" or "Hochofen", a continuous in-

stallation for the smelting of iron, of still greater height, which enabled completely fluid iron to be obtained in a stream, and thus originated the whole process of the casting or founding of iron.

Belgium still retains to-day, as stated, the position of being one of the chief countries associated with iron and steel, and also fuel technology, and it is only natural therefore that the very latest methods of super-power station practice are well represented. For example, great attention is being given to the use of super pressures and temperatures of steam, and in this connection the Société Intercommunale Belge d'Electricite Monceau is to operate at 823 lb. per sq. in. and 897 deg. fahr. superheated steam temperature, while the Union des Centrales du Hainaut at Quaregnon is building a boiler plant for 951 lb. per sq. in. pressure and 887 deg. fahr. superheated steam temperature. Another famous Belgian power station of course is Langerbrugge, near Ghent, belonging to the Centrales Electriques des Flandres et du Brabant.

It is the intention, however, to devote the present contribution principally to a description of one of the latest Belgian superpower stations, that is Schelle, belonging to "L'Inter-Escaut", and I am able to do this largely through the courtesy and assistance of MM. Société Anonyme des Foyers Automatiques of Paris, whom I have to thank most sincerely in the matter, and especially for the photographs reproduced herewith.

The construction of the Schelle super power station was decided upon in 1927 by arrangement between the Société d'Electricite de L'Escaut and the Société Intercommunale Belge d'Electricite, and work was commenced in the spring of 1928 by an associated Company formed jointly for the purpose, the Societe Generale Belge de Production d'Electricite, commonly known for short in Belgium as L'Inter-Escaut.

Fig. 2—Interior of furnace showing air-cooled front wall and openings in arch for vertical burners.

The site of the station is on the River Escaut, just near the junction with the River Rupel, and right in the center of the thickly populated and highly industrial provinces of Antwerp and Brabant. The overhead transmission system will be connected up with that of the power stations in the Liege, Charleroi, and other areas in Flanders, which, of course, is easily arranged as Belgium is a country of extremely small area.

The Schelle super power station is designed for an ultimate capacity of 500,000 kw. and will use coal from seven different provinces in the Low Countries, including the areas of Bellevue, Bonniere, Wilhelm Sophia, and Herve-Wargifosse, the average analysis of these different coals being from 8.5 to 12.0 per cent volatile matter, 7.0 to 26.0 per cent ash, and 3.5 to 8.0 per cent moisture, with a heating value of 10,890 to 14,524 B.t.u. per lb.

The boilers are fired with pulverized fuel, and the plant is equipped with air heaters, feed-water

Fig. 3—Interior of furnace showing water-cooled side wall, rear wall and part of water screen.

heaters, and degassing equipment for the feed-water, to prevent corrosion. Further, the steam pressure is 498 lb. per sq. in. and the superheated steam temperature 797 deg. fahr., while the turbo-generators are to run under conditions of 10,500 volts with 50 periods per second, and distribution of the power at 70,000 volts.

The first section of the station, 90,000 kw., has now just been completed (November, 1930), and a general view of the plant is given in Fig. 1. The equipment includes 6 boilers of the Babcock and Wilcox semi-marine type, and 3 turbo-generators each of 30,000 kw. Each of the boilers has a heating surface of 13,099 sq. ft. and the air heaters, 42,517 sq. ft. The normal evaporation is 137,750 lb. per hour, with an overload of 172,000 lb., the average temperature of the feed-water as going into the boilers being 329 deg. fahr., with a superheated steam temperature, as stated, of 797 deg. fahr.

All six boilers are fired with the Lopulco-Roubaix system of pulverized fuel, of which a diagrammatic illustration is given in Fig. 6, being a vertical section of the whole arrangement. The raw coal on arrival is discharged to the lower storage hopper "*A*", from which it passes down to the Hardinge mills "*B*",

operated on the usual principle with gravity separation using a current of heated air in conjunction with overhead cyclone separators "*C*" placed high up under the roof of the station. From here the pulverized coal is delivered to the closed bunker "*D*", and discharged by the new Lopulco-Duplex motor-driven feeders "*E*" to the Lopulco fish-tail

Fig. 4—View of boiler at burner level.

burners "*F*" fixed in the top of the combustion chamber "*G*", firing vertically downwards. The furnace is fitted with water-cooled side walls and back walls operating under pressure in series with the boiler, and the ash is taken out at intervals from the bottom of the combustion chamber by the two hoppers "*H*", passing to a water sealed ash conveyor.

The gases, after passing through the boiler and superheater ("*I*" and "*J*"), are delivered to the air preheater "*K*", which is served by the electrically-driven, induced draft fan "*L*", discharging to the chimney base "*M*".

The main bulk of the air for combustion passes from the air heater at a temperature of 413 deg. fahr. to the combustion chamber "*G*", which it enters through the hollow front walls, in its passage through which its temperature is still further increased. A proportion of the air at 413 deg. fahr. also goes to the feeders and burners. The total volume of the combustion chamber between the arch and the horizontal water screen is 9,888 cu. ft.

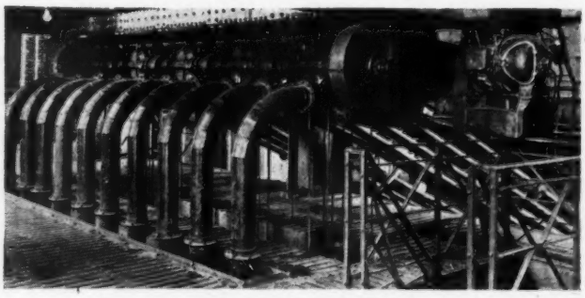


Fig. 5—Duplex pulverized fuel feeders.

The furnace contains 24 tubes in each side wall, with 36 tubes in the rear wall and an inclined water screen of 18 tubes, the total heating surface of water-cooled steel tubes in the combustion chamber being 1367 sq. ft.

Further, each combustion chamber has 10 Lopulco burners and 5 horizontal Duplex feeders for the pulverized fuel, each of which supplies two burners. The front wall of the combustion chamber and the front portion of each side wall are of the sectionally supported, air-cooled construction on the Roubaix or Dietrick system of suspended blocks, allowing free expansion and contraction. In addition, the top of the chamber is formed of Roubaix suspended firebrick arches, in which the row of ten burners are installed.

This first section of the plant, comprising six boilers, has two chimneys of a total height of 384 ft. and 29.5 ft. diameter at the base, one chimney serving three boilers.

With regard to the pulverizing equipment, the Station is specially designed to cope with great

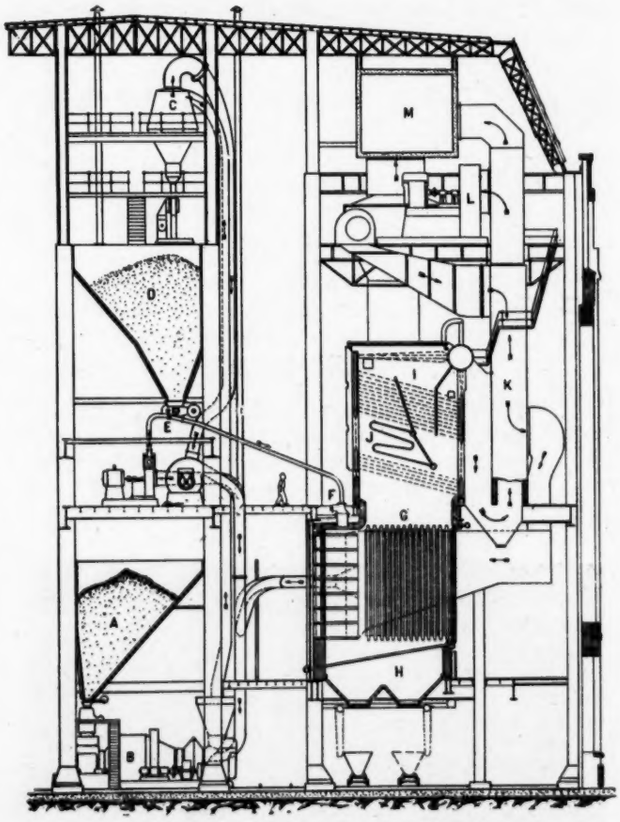


Fig. 6—Sectional elevation through Schelle plant.

fluctuations in the demand for power, and, therefore, has a considerable reserve in the pulverizing and coal storage plant. The installation comprises 6 Hardinge mills operated, as stated, on the usual gravity separation principle with a current of hot air which also serves as a drying medium, with separation of air and coal by means of a cyclone separator. Each mill has a capacity of 10 tons of coal per hour, giving a degree of pulverizing equivalent to 98 per cent through a 100 per cent mesh screen, so that in

(*Continued on page 46*)

Engineering Aspects of Interchange of Power With Industrial Plants*

Establishment of Means and Facilities for Utilizing Massed Resources to Serve the Power Requirements of Individual Industries

By

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NEW YORK

Economical operation can be effected and overhead costs greatly reduced in a great many cases where public-utility or other steam-generating or hydro power plants find it possible to hook up with large industrial operations. The advent of high steam pressures has largely increased these possibilities and extended the engineering problems involved in their proper solution. The engineer must seek the maximum overall economy with minimum investment having regard for reliability of service, and then work out a plan for the undertaking that will be to the equal advantage of all parties at interest.

INTERCHANGE of power may be secured by means of some plan of interconnection. The term "interconnection" carries the thought of tying together the transmission or other electrical facilities of two or more power systems.

Let us, for a moment, review the accomplishments of interchange of power by interconnection between public-utility systems.

About 25 years ago, in the United States, isolated or independent plants for the supply of electrical service to a community began to give way to the grouping of adjacent systems by the tying together of the transmission systems. This was primarily done for protection of service in emergencies and could be successful only when each company had a mutual regard for the common interest. As the advantages of interchange of power became better understood and appreciated, independent operating companies were brought under a common financial control through holding companies. Interconnection, more intelligent load dispatching, the use and development of the most economical power sources, standardization and interchangeability of equipment, better system planning, and many other advantages logically followed the extension of holding-company control.

Progress in interconnection has reached a point where the principal electric power systems between the Mississippi River and the Atlantic Coast and from the Gulf of Mexico to and across the Canadian boundary line may now interchange power. This territory comprises an area of approximately 900,000 sq. mi., about twice the size of Germany, France, and England combined.

Within a relatively short time interconnecting links will be extended to include other power systems west of the Mississippi, making the area of the then connected systems in excess of 1,500,000 sq. mi., in which there is a population of approximately 98,000,000. Some 20 major power systems and many more of smaller size serve this territory, in which there is a total of about 20,000,000 kw. in power-generating capacity. Each of the major power systems comprises a transmission network within itself, interconnecting from 400,000 to 2,000,000 kw. in power-generating facilities with interconnecting ties having capacities ranging from 25,000 to 125,000 kw. This great spread of interconnection has resulted in benefits to the power systems in the following respects:

1. Greater leeway in the choice of plant sites
2. Decrease in generating capacity due to diversity
3. Decrease in spare generating capacity
4. Increase in size of generating units, resulting in lower unit cost
5. Staggering of new construction
6. Making hydro capacity firm capacity
7. Making possible the use of more economical units.

The choice of plant site for a new generating station is influenced by three major considerations, namely: center of load, availability of condensing water, and the delivery and cost of fuel.

Interconnection tends to eliminate the restrictions due to load. As illustrating this statement, one may cite cases of such stations as Stanton, Deepwater, Trinidad, Toronto, Philo, Gorgas, and many others. All of these stations supply power into a transmission network of considerable extent, thus permitting selection of plant site to secure minimum operating cost because of cheaper fuel and increased available capacity because of an adequate supply of condensing water.

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One advantage secured by interconnecting is the decrease in capacity due to diversity. The magnitude of this diversity may perhaps best be illustrated by the following cases:

1. The Southeastern system interconnects the Alabama-Mississippi systems (325,000 kw.) with the Georgia-South Carolina systems (225,000 kw.) and the Tennessee system (136,000 kw.). Diversity in loads adds about 40,000 kw. effective capacity to the combined system, about 5 per cent of the total.

2. Niagara-Hudson system connects the Buffalo System (900,000 kw.) with three systems in the eastern part of the State (375,000 kw.). Load diversity adds between 30,000 and 50,000 kw. to the combined systems, or about 3 to 5 per cent of the total.

3. Pennsylvania-New Jersey interconnection ties Philadelphia Electric Company (950,000 kw.), the Public Service Company of New Jersey (860,000 kw.), and the Pennsylvania Power & Light Company (831,000 kw.). Load diversity adds over 300,000 kw. to the combined system, or nearly 12 per cent of the total.

It becomes possible, therefore, to reduce the total plant investment by 5 to 10 per cent because of system diversity when adequate transmission facilities are provided to distribute to the entire system the necessary reserve or standby capacity.

A further saving results in the decrease in spare equipment necessary to maintain reliability of service. Spare generating equipment in capacity equal to the largest single unit on one system becomes adequate spare for the interconnected system.

Increase in the size of generating units, which becomes possible for plant installations on interconnected systems, makes a substantial lowering of unit costs. A station, either hydro or steam, containing large units may be developed on the system or portion of a system, and later a station developed at another location, thus alternating or staggering the construction program to bring in only the additional capacity properly to meet the growth in load.

The possible saving in capital investment may be illustrated by the Toronto Station. This station in its first construction stage consisted of two 35,000-kw. units, which were installed at an average cost of $128 per kilowatt of capacity. In the next stage two additional 35,000-kw. units were added, making the average cost for the 140,000 kw. of installed capacity $114 per kilowatt. Had this station been constructed as a complete unit, under an interchange agreement, the generating equipment, instead of four 35,000-kw. units, would probably have been two 70,000-kw. units, which could have been constructed at a cost not in excess of $100 per kilowatt. The total cost of the output, including fixed charges on capital investment, operation, and maintenance, would have been 15 to possibly 20 per cent less for the station of larger generating units.

It is perhaps necessary to make some explanation of the statement that interconnection makes hydro capacity firm capacity. The usefulness of a hydro plant is limited to the ability of the system to absorb the capacity and energy that the stream flow as regulated by the available storage may develop. During low stream-flow periods the available capacity of run of river hydro plants may be supplemented by either storage hydro or steam plants, and the capacity of run of river hydro plants then becomes firm or useful capacity.

Many of the larger systems in the interconnected systems referred to are served by hydro as well as steam-generating stations, and to the extent that the systems are not so served the tendency is to interconnect with systems having generating facilities of different characteristics. Steam and hydro stations on a system supplant each other because of different characteristics.

The economy of combining such generating facilities results from the fact that the available output of the hydro station may be more fully utilized. There is thus provided a larger system into which the hydro energy may be poured, making it possible, during the high-water periods, to run the hydro plant to full capacity on base load, and during low-flow conditions the full capacity may be used during the short peak period, placing the economical steam stations on base load.

Large blocks of hydro energy available during high-flow seasons may be utilized to replace steam-generated energy, while during low-flow seasons when but little hydro energy is available the full hydro-plant capacity may be used daily for short periods on the system peaks. In this manner, every drop of water up to the installed hydro capacity may be effectively utilized. Such complete utilization, however, is only possible when the hydro plants are connected into systems having a minimum night or week-end load requirement sufficient to absorb the flood-flow hydro capacity and energy. With large hydro projects such load is rarely available except by extension of the interconnected system over a considerable geographic area without reference to political lines of division.

There remains, however, another condition that must be satisfied to secure the full advantages of the physical possibilities. The administrative direction must be in harmony with the economical advantages of the interconnected systems, a condition fully satisfied through ownership or lease of the hydro plant. In those cases where the ownership of the hydro plant, particularly if on streams where complete seasonal or yearly regulation is not obtained, lies with other interests, a mutually clear understanding of the common interests must obtain. It is extremely difficult if not impossible to express in a contract all conditions to secure the full utilization of all available power. The utility companies transmitting and disposing of

the energy must say how and when the hydro plant is to be operated. The operations of the hydro as well as other generating stations must be under the immediate direction of the system load dispatcher unhampered by other restrictions.

The great development of and economic advantages gained to the utility systems of the United States during the past two decades by interchange of power through massed resources have been discussed at some length because, for similar reasons, it is believed that a great opportunity is offered for cooperation between industrial plants and utility systems. The next two decades should witness even greater strides in extending the interchange of power between industrial plants and utility systems through massed resources.

Let us now consider interchange of power with industrial plants; and in this discussion it is the purpose to think of interconnection as the means employed to secure the advantages of massed resources of power production.

Within the area over which this network of interconnected utility systems extends, nearly 200 industrial concerns have, during the past few years, established new plants, with boiler equipment designed to operate at a pressure of 300 lb. or higher. Nearly two-thirds of this number installed power-generating equipment aggregating approximately 500,000 kw. of capacity. The advent of high pressure has made it possible for the industrial plant to get some or all of its power requirements from the steam that is subsequently used for process or other heating operations. There is, beyond doubt, a very much larger number of industrial plants in operation at less than 300 lb. pressure supplying the multiplicity of power and heating requirements of industrial enterprises. An industrial plant often requires process steam as well as electric power, and frequently some form of waste heat is available. Steam and electric power requirements of an industrial plant do not usually coincide, either hourly, daily, or seasonally, and these requirements do not, except in a general way, synchronize with the liberation of waste heat or the possible production of surplus electric power. A great field of opportunity is here presented for cooperation between utility and industrial companies to bring about a massing of resources of power production.

To secure the maximum degree of reliability and economy of power service and the fullest utilization of any waste heat or usable surplus power, some arrangement must be made to bring about a massing of the industrial and utility companies' resources of power production. This is hardly possible if the utility company limits its activity solely to the furnishing of electric service, particularly if the utility company adheres rigidly to an established schedule of rates. A discussion between utility and industrial people frequently starts with a mutual distrust of each other's cost statements, which leads to dickering and may end in the industrial company determining to be wholly independent in its entire power service. Recently, a broader and more liberal view has prevailed, and progress is being made in bringing about an agreement to the mutual advantage of both interests. To some extent, this change of attitude may be due to a better understanding of unity of interests.

The Conowingo (Susquehanna River) development of the Philadelphia Electric Company illustrates this point. The stream flow varies yearly as well as seasonally between wide limits (minimum 3000 sec-ft. to a maximum of 750,000 sec-ft.) and the day-to-day variation is frequently of considerable magnitude. The installed capacity of 250,000 kw. is used during high water at nearly 100 per cent load factor to carry the base load of the Pennsylvania-New Jersey interconnected systems on which the minimum load is approximately 460,000 kw. During low stream-flow conditions this full capacity is used for short periods on peak. In this plan of operation the total annual available output of some 1,350,000,000 kw-hr. is poured into the interconnected systems and profitably utilized. Without this mutually cooperative arrangement a considerable portion of usable hydro energy would be lost to the disadvantage of large numbers of domestic and industrial customers, and, in fact, is actually so lost on large undertakings where the administrative operation is by different authorities.

Interchange of power by means of the physical interconnection of different systems is thus the employment of massed resources. The unification of financial and administrative control extends the advantages of massed resources to other features, such as resources of capital and organized personnel. Larger and better projects may be developed and more intensive and careful study by a skilled organization may be devoted to the improvement of service and betterment of operating results.

Among the means that may be employed to secure the advantages of massed resources of power production, with respect to utility and industrial plants, there may be mentioned the following:

1. The interconnection of the electric circuits securing advantages of protection of service, diversity of load conditions, economy of operation, etc.

2. The establishment of jointly owned plants and facilities, supplying to the industrial plant electric, steam, or other power service, utilizing the utility system as the reservoir from which to draw or into which any and all surplus electric power may be poured.

3. The building and operation of plants and facilities by a utility company near the industrial plant, supplying such power service as required by the industrial plant, making up any deficiency from or

taking any surplus electric power on the utility company's power system.

In the first case there are the possibilities of all the advantages of interchange of electric power presented by interconnection between different utility systems with the further advantage, usually, of a different character and greater degree of diversity of load.

It is, however, the last two cases that present the greatest possibility for mutually advantageous arrangement between industrial and utility plants and that make the engineering studies to secure maximum economic results most interesting.

In the establishment of jointly owned plants or the allocation of a portion of the plant facilities to the service of the industrial plant, the total investment may be minimized. Many plant facilities such as real estate, railroad sidings, coal- and ash-handling equipment, etc., need not be duplicated. Spare equipment may serve as spare for both the industrial and utility. The organization for operation and maintenance may be spread over both operations.

A good illustration of the second case is the Deepwater Station, located on the New Jersey side of the Delaware River, just opposite Wilmington, Del. This station is jointly owned by the American Gas & Electric Company and the United Gas Improvement Company, with a portion of the plant allocated to the services of the E. I. du Pont de Nemours & Co.

The first two companies are important utility companies, with a large and rapidly growing electric light and power business. The du Pont company is one of the largest industrial companies, manufacturing widely diversified products and having a substantial and increasing need for both process steam and electric power. The combined additional electric-power requirements of the two utility companies was in the order of some 100,000 kw. demand and 400,000,000 to 600,000,000 kw-hr., annually while the industrial company wanted 200,000 to 400,000 lb. per hour of process steam at 180 lb. pressure. Mutual discussion between the three companies led to the conclusion that they could combine their needs to the economic advantage of all concerned. The power companies organized a company to build and operate a power station for their joint interests and to enter into a contract to furnish steam and electric service to the du Pont company.

After a carefuly study of plant investment and operating costs the power companies adopted a station designed to operate with a boiler pressure of 1400 lb. The initial installation includes six boilers, each of a capacity of about 330,000 lb. of steam per hour. Two such boilers are allocated to the service of the du Pont company, leaving two boilers, one standard and one reheat boiler, for each of the utility companies. The station is laid out on the unit plan with one standard and one reheat boiler in each of the utility sections and two standard boilers in the center or du Pont section. The initial turbine installation consists of two cross-compound units, each of a capacity of 55,000 kw. The high-pressure elements of these compound units are identical in design with the 12,500-kw. unit in the du Pont section. The exhaust from the du Pont unit, however, which at maximum load amounts to 530,000 lb. per hour, goes directly to evaporators which furnish 400,000 lb. of steam per hour at 180 lb. pressure.

Steam from the evaporators passes through live-steam superheaters bringing the temperature up to 440 deg. fahr. before it is sent out on the du Pont lines. The condensate from the evaporators is returned as feed to the boilers, making a closed cycle. The du Pont company returns or makes up the condensate of its steam supply and, to the extent that the return is at high temperature, less heat is required in the evaporators.

The essential features of the contract between the utility companies and the du Pont company are as follows:

1. The du Pont company pays in monthly instalments a sum representing a reasonable return on the investment in that portion of the plant facilities allocated to their service.

2. It pays the proportionate share of all direct operating and maintenance costs, including fuel.

The du Pont company is thus entitled to all electric power generated by the steam that passes through its high-pressure turbine unit, and should its need for process steam be in excess of that required to produce the necessary supply of electric power, the excess power flows into the utility system and is credited to the du Pont company. On the other hand, should its need for electric power at any time exceed the production of the generating unit, power will be drawn from the utility company's system.

The second element of the du Pont company's monthly charge is determined by the ratio that the total heat supplied to its generating unit bears to the total heat supplied to all generating units. As a result of this arrangement it is given full access to all station-operating records and may even purchase or designate other sources of fuel if it believes lower operating costs would result.

The combined full utility and industrial load will require the operation of five boilers, leaving the sixth as spare for all companies. Furthermore, either utility company may, at any time, take any unused capacity of the other, paying only the proportionate operating and maintenance costs. Thus, to the extent that their respective loads do not synchronize, each company has the privilege of fully loading the unused capacity of the other without increasing its share of capital expense. An incentive is thus created that should result in keeping the station as

nearly fully loaded at all times as possible. Should this occur, the net effect will be to the benefit of all parties, as in this manner the unit station-heat costs will be less because the total cost will be spread over a larger output.

This is believed to be one of the largest instances, if not the first instance, in this country of utilizing the massed resources of utility and industrial companies for power production. The successful working out of this arrangement should open up many new opportunities for the engineer in the problem of interchange of power between utility and industrial plants.

As an example of the third class—that is, of the utility company owning and operating the plant and facilities—may be cited the case of a steel company wishing to change its rolling mills and other steam-engine-driven equipment to electric-motor drive. The steel company produces finished products in an amount of approximately 90,000 gross tons per month. It was found that, after making use of coke-oven and blast-furnace gas in heating furnaces and other metallurgical operations, sufficient gas was available to supply the steel company's electric-power requirements after complete mill electrification. The steel company's electric-power requirement will then be about 300,000,000 kw. annually, with a maximum demand of 54,000 kw. The available waste gas will produce, over and above the steel company's requirements, a surplus of some 40,000,000 kw-hr. annually. The steel company either would have to install complete spare equipment or relay its electric-power service from the utility company's power system, thus either materially increasing its annual capital charges or adding to its operating charges for reserve or standby service.

An industrial company such as the steel company is usually not prepared to make large capital investments, except under pressure of necessity, unless the annual return on capital investment is greatly in excess of that required in the diversified power service of a utility company. This situation led to the suggestion that the utility company build, own, and operate the power plant and facilities, purchasing the waste heat from the steel company at substantially the equivalent cost of other fuel, and furnish the steel company with its entire electric-power requirements on a cost basis to yield a proper return on the investment.

The utility company could build a station designed to operate at 1400 lb. pressure, instead of 400 lb. as contemplated by the steel company, providing no spare generating equipment. The utility company could relay the steel company's service with the spare equipment required for its other service. Such a plant, in addition to supplying the steel company's requirements, could generate some 100,000,000 kw-hr. annually at a cost that could advantageously be poured into the utility company's system. The net result will be to furnish the steel company's entire electric-power requirement at a cost comparable with any cost to itself and to save the steel company an investment of something over $6,000,000 in power-station facilities and to increase the annual return on the moneys to be spent by the steel company on its electrification program from about 20 per cent to about 25 per cent. While as yet no actual contract has been consummated to carry out this program the general principles have been accepted pending the development of details. The resources will be massed, no usable product wasted, and capital investment conserved.

A case now under consideration is that of a large manufacturer using some 3,000,000,000 lb. of steam per year for process and heating and at the same time buying and generating electric power up to a maximum demand of 42,000 kw. The manufacturer is faced with the necessity of abandoning one of two large boiler plants, and being thus faced with rehabilitating his steam and power supply, can effect substantial gains by building a high-pressure boiler plant and generating by-product power. Here again even greater overall results can be obtained by the public-utility company building the new plant and serving both the steam and electric-power requirements, primarily because the utility company can make a materially greater use of the investment in plant facilities.

Another case recently under consideration was a group of stockyard and packing-house companies whose plants are located close together. Their combined maximum demand for steam is almost 2,000,000 lb. an hour, now served from eight relatively low-pressure boiler plants, while they generate or purchase about 130,000,000 kw-hr. a year. Estimates of a central high-pressure steam station producing by-product power, including, of course, fixed charges on the new investment, show very substantial economies over the present operating costs, but the point to emphasize is that the overall saving is a maximum when the public-utility company is associated with the new enterprise, as this permits minimizing investment in spare or reserve plant capacity; it permits maximum economical use of all by-product power; and it supplies, in the most economical manner, electric power which at times is required in quantities greater than is available from the steam then used.

The economic advantage of expanding high-pressure steam through engines or turbines to make by-product power before the steam is used in process work is being lessened by two factors, namely: the constantly improving thermal performance of modern large turbine installations and the higher-cost of boilers, evaporators, and other equipment required for by-product power production with high steam pressures.

Only a few years ago, a station thermal performance of 20,000 B.t.u. per kw-hr. was regarded as excellent. Many large central-station plants are now being designed for approximately 12,000 B.t.u. By-product power may be obtained for about 5000 B.t.u. per kw-hr., but in high-pressure plants, evaporators are usually necessary to insure scale-free water in the boilers, and as much as 6000 B.t.u. per kw-hr. may be required. The ratio has thus been changed from about 4 to 1 to 2 to 1. If to obtain by-product power it becomes necessary to make large capital investment or if the rate of annual fixed charge is high, the economy of an independent high-pressure plant to supply the service to an industrial company is thus greatly reduced. The economic results of a station supplying combined service to an industrial plant and a utility system may, however, be quite improved and in any event should be better than is possible if each develops independently.

The principles of contractual relations between the industrial and power company are simple, but their application may be complex.

In principle the industrial should pay the power company a reasonable rate of return on all investments made on its account and also pay its proper share of all operating costs. In practice it is often desired to reduce the payments to unit rates for steam and electric power.

While it is relatively simple to ascertain the probable costs for any given set of operating conditions, it is difficult to determine unit rates which will be equitable at all probable ranges and conditions of electric load and steam flow.

For instance, if by-product power from steam be involved, then the combined unit cost of saving both steam and electric power is a minimum when the investment in steam capacity is fully utilized and when the electric-power requirement is just that of the by-product power available from this amount of steam. Any unbalanced conditions from this exact relation between the quantity of steam and of electric power will increase the combined unit cost. Hence, the unit rates for each should bear some relation to the quantity of the other, and in the limit be equitable on the one hand for furnishing steam only a portion of the time and on the other hand for furnishing electric power only a portion of the time. This requires a very careful survey of all probable operating conditions and a clear understanding between the engineers of both companies.

Many other examples of the interchange of power with industrial plants might be cited. There are undoubtedly thousands of opportunities for the establishment of means and facilities to utilize massed resources to serve the power requirements of industrial plants. The advent of high steam pressures has largely increased these possibilities and extended the engineering problems involved in the proper solution. The engineer must seek the maximum overall economy with minimum investment, having regard for reliability of service, and then work out a plan for the undertaking that will be to the equal advantage of all parties at interest. These problems are of special interest because of the many new and unusual factors involved.

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Modern Power Practice in Belgium

(*Continued from page 40*)

conjunction with the storage bunkers the pulverizers need not operate for the whole of the 24 hours. Thus, each of the boilers, which are entirely independent self-contained units, has a storage of 100 tons of raw coal in the hoppers before pulverizing, and there is also ample capacity, as indicated in Fig. 6, in the closed pulverized coal bunkers.

Since the station has only just been completed no detailed performance results are of course yet available, but the figures previously given for the evaporation, amount of coal burnt, steam temperatures, and other items can be taken as approximately correct.

The method of firing pulverized fuel, as installed at Schelle, is playing an important part in Belgian power stations as indicated by the fact that similar installations have been made in Quaregnon, Bressoux, Alost, Sweveghen (Soc. Intercommunale Belge d'Electricite), and Moll-Donk (Soc. Electrique de la Campine).

No discussion of present-day power practice in Belgium would be complete without at least a brief reference to the Langerbrugge Station, belonging, as previously stated, to the Centrales Electriques des Flandres et du Brabant. This is undoubtedly one of the most important stations in the world since it has been the scene of major pioneering work. The Company has always been prominent as regards the adoption of high pressures and temperatures of steam, and, at present, is identified with the operating, in an adjacent establishment, of a low-temperature carbonization plant according to the Salerni process.

Further, a Benson boiler is now running in this plant under the actual "critical" conditions, that is approximately 3200 lb. per sq. in. pressure, when water at 706 deg. fahr. is converted into steam without change in the volume, no latent heat being absorbed, although in practice of course the steam is superheated above the critical temperature.

The most important aspect of Langerbrugge, however, is in connection with the development of what will undoubtedly be the next stage in power station technique, that is, direct association with a

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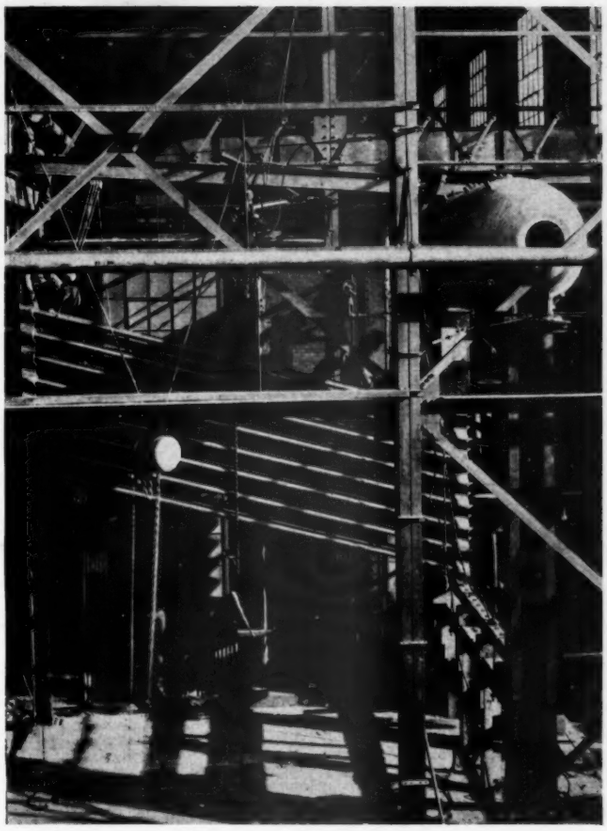

1200 lb. pressure, sectional header boiler in course of erection at the plant of the Masonite Corporation Laurel, Miss

Operating Experience with Twelve Hundred Pound Pressure Boilers at the Masonite Corporation

By
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This article presents a resume of the operating experience of the Masonite Corporation with their 1200 lb. pressure plant. In this plant, high pressure steam is used to explode wood chips into fiber, the process being accomplished without destruction of any of the material binders originally present in the wood.

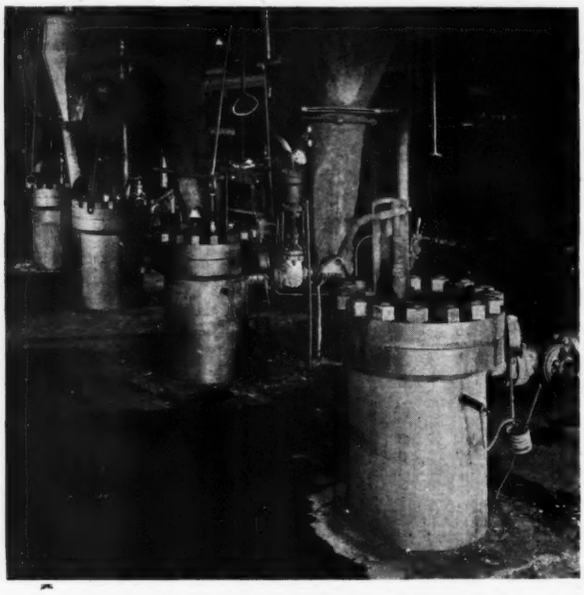
THE Masonite Corporation has the distinction of being the first industrial plant to use steam pressures in the neighborhood of 1200 lb. per sq. in. for process work. Their product, "Masonite", is made from sawmill wood waste by a process which, through the use of saturated steam at high temperature and pressure, explodes the wood chips and produces a resultant wood pulp consisting of long fibers encrusted with the original wood lignins.

By the use of the steam exploding process the high power cost and the laceration of fibers entailed in the mechanical grinding process and the loss of 40 to 50 per cent of the material, which results from the chemical pulp process, are avoided. The proper combination of degree and duration in temperature results in virtually complete separation of the wood fibers without noticeable deterioration in either the cellulose or lignin.

In present practice the chips are subjected to a low pressure of 200 lb. for from 10 to 15 seconds, and then to a pressure of 1,000 lb. for from 3 to 5 seconds before blowing them from the gun. This softens the lignins without damaging the fiber. Complete separation of the fiber can be obtained by applying the higher pressure direct for 6 seconds, but the resultant pulp is not as good.

Description of Boilers

The two 1200 lb. pressure boilers are of B. & W. manufacture and are of the cross-drum, sectional-header type. The first boiler was put into service during the summer of 1926. This boiler contains 3820 sq. ft. of heating surface and has 2 in. O. D. number 5 generating tubes. It is fired with wood



Guns which use steam at 1100 pounds pressure for converting wood chips into fiber.

refuse in a Dutch oven having a grate area of 120 sq. ft. and a height above the grates of 6 ft., and is normally operated at from 200 to 250 per cent rating.

The second boiler was put into service during the summer of 1929, and this boiler contains 3800 sq. ft. of heating surface and has 3¼ in. O.D. 5/16 in. thick generating tubes. It is fired with coal by a Westinghouse single retort stoker. The furnace has a volume of 648 cu. ft. and is normally operated at a rating of 200 to 300 per cent.

Operating Experience

Only those experiences which have not previously been published will be included here.

The 2 in. tubes have proven to be more immune to failure, due to scale formation, than the heavier wall 3¼ in. tubes. This is directly due to the thinner wall sections. Another advantage in favor of the thinner tubes is the lower flue gas temperatures.

Although condensate from the low pressure drying system is used for boiler feed purposes, the boiler feed at times contain 4 p.p.m. of hardness expressed as calcium carbonate. This hardness is due entirely to leakage of the flash steam condensers.

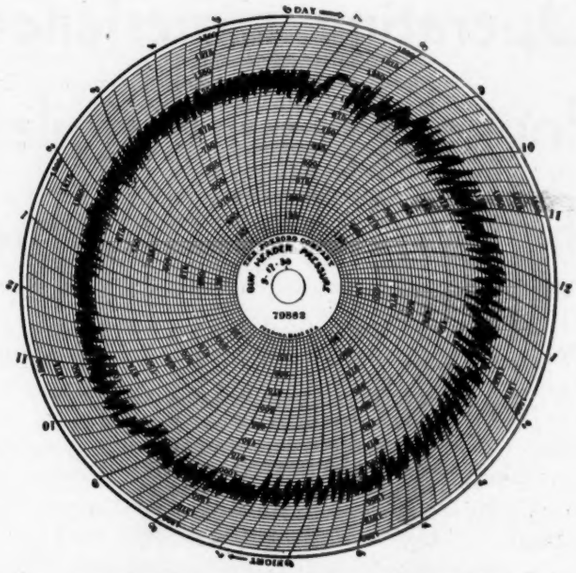
The only tube failure to occur in the past seven months was the failure of a tube in the bottom row of the second high pressure boiler. This failure occurred on a Tuesday night but the boiler was kept operating at 250 per cent rating until the following Sunday morning. This fact has been proof to the operating personnel that the operation of boilers at this pressure is no more dangerous than the operation of boilers in the lower pressure ranges.

The tube failure previously mentioned was caused by the deposition of a dried-out sludge on the bottom of the lower row of the tubes. Since the boilers were opened for an insurance inspection two weeks before the failure occurred, it is apparent that this could not have been prevented. The boiler was left dry during the two weeks following the inspection due to the fact that the mill was not running and the boiler room was completely shut down making it impossible to pump up the boilers.

An analysis of the deposits causing this failure is as follows:

Silica	17.1	per cent
Iron oxide and alumina	22.4	" "
Calcium phosphate	1.4	" "
Calcium carbonate	15.5	" "
Magnesium hydrate	9.7	" "
Magnesium carbonate	2.6	" "
Magnesium silicate	29.2	" "
Copper oxide	1.2	" "
Zinc oxide	.5	" "
	99.6	per cent

As can be seen from the above, the sludge is a typical silica sludge and, with the exception that calcium silicate takes the place of magnesium sili-



A typical pressure chart taken from the high pressure header.

cate, has the same chemical analysis as the hard scale present in the low pressure boilers. This is to be expected as the circulating water through the flash steam condensers is the low pressure boiler feed.

In order to minimize the danger of hard scale formation in the high pressure boilers, it was decided to maintain a sodium carbonate alkalinity of between 80 and 130 p.p.m. and a phosphate concentration of

from 50 to 100 p.p.m. Under these conditions, no scale has been formed and no corrosion or pitting has taken place.

The average analysis of the boiler waters over a four months period has been:

	P.P.M.
Sodium hydroxide	36.0
Sodium carbonate	37.1
Disodium phosphate	76.0
Sodium chloride	27.3
Sodium sulphate	90.0
pH	9.6

The operation of these boilers is no different from or more difficult than that of any other boiler. The

Close-up view of sectional headers showing double recessed tube openings.

only difference is in the length of time, commensurate with safety, that it takes to bring a boiler on the line or to cool down.

The water level has no tendency to fluctuate due to the high density of the steam which allows the steam bubbles to escape with little violence.

Determinations of the moisture content of the steam leaving the boilers were made. In no case did the amount exceed .80 per cent.

Auxiliaries and Appurtenances

The boiler feed pumps are of the steam-driven duplex type. Quite a lot of trouble was experienced with the valves. This trouble consisted of cuts in the seat and disc. This was eliminated by stelliting the discs and seats.

Feed water regulation is by hand due to the nature of the load.

The safety valves receive severe service as can be seen by the accompanying pressure chart. There are two valves to the boiler and the first is set to blow at 1175 pounds.

The blow-down valves are a source of annoyance. They are of the globe valve type and are very hard to keep tight.

No low and high water alarms are installed in the water column but a recording thermometer is installed on the steamline from each boiler. This recording thermometer has an alarm contact, set at three degrees superheat, which is connected to a siren. It has been found that under low water condition, the steam is slightly superheated.

Future Work

A boiler feed regulator with a positive shut off is now being developed by the Northern Equipment Co. This regulator will be given a trial on one of the 1200 pound pressure boilers.

By the end of the year both boilers will have been changed from wood and coal firing to natural gas.

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Modern Power Practice in Belgium

(*Continued from page 46*)

variety of adjoining works using low pressure steam for heating and boiling, so as to avoid the latent heat of steam loss, electricity for manufacturing purposes being generated during the off-peak load period at night.

Another interesting station is Bohlen in Saxony, where part of the exhaust steam from the turbo-generators is used for drying the raw lignite for briquetting, that is, the whole establishment is a combined electricity generating station and lignite briquetting works, this latter industry of course necessitating the drying of the lignite containing about 50 to 55 per cent moisture down to 15 per cent before compressing without a binder.

Langerbrugge, however, is much more advanced, and some of the auxiliary industries in adjoining works, apart from the Salerni process plant, are the manufacture of carbide, by the Soc. Belge d'Electro-Chemie, and the production of caustic potash by the electrolysis of potassium chloride, by the Union Chimique Belge, over a dozen separate establishments being now at work.

Three of the outstanding problems in steam driven power stations to-day are the loss of latent heat to the condensers, the fact that raw coal is being burnt and all the valuable by-products that could be recovered by low temperature carbonization merely consumed as fuel, and the improvement of the load factor by utilizing electricity at night. In these three fields, as well as in the latest technique in ordinary steam and power generation, a prominent part is being played by Belgian engineers.

How to Check Air Heater Performance

By B. J. CROSS

Combustion Engineering Corporation, New York

THE efficiency of an air heater may be computed on the ratio of the heat absorbed by it to the heat supplied to it. The efficiency may also be expressed as the percentage of the maximum possible reduction in gas temperature or maximum possible increase in air temperature that is effected by the heater. However, as with the economizer, efficiency is not a fair basis on which to judge the performance of an air heater. The measure of its performance should be the degree to which it meets its design requirements.

Practically all air heaters are designed to operate "counter flow," that is, the air and gas are passed through the heater in opposite directions so that the hottest air receives heat from the hottest gases and the average temperature difference between the air and the gas is maintained at a maximum.

One disadvantage under which the air heater performs is due to the fact that the heat absorbing medium, air, has a lower heat capacity than the gases from which the heat is to be absorbed. This disadvantage is further increased for the reason that the weight of air is less than the weight of gases, even when 100 per cent of the air used for combustion is passed through the heater. In actual practice about 70 to 80 per cent of the total air required is passed through the heater, the remaining portion passing into the furnace and setting through unavoidable leaks. As a result of this difference in heat capacity of the two mediums, the temperature of the air increases more rapidly than the temperature of the gases decreases and the head available for heat transfer becomes lower toward the hot end of the heater. Theoretically, in a counter flow heater, the final temperature of the air can be made to equal the initial temperature of the gases. This would require an air heater of infinite surface in which the heat transfer would be zero. The practical limit to the final temperature of air is the point where the rate of return in heat absorbed for an increment in heater surface ceases to show a profit on the investment.

The practical limit in temperatures at the cold end of the heater is the point where condensation of moisture may occur on the heating surfaces. Condensation may occur at this point even when the average temperature of the gases is above their dew point, due to lower film temperatures at the surfaces of the heater elements. This film temperature must, of course, lie between the final gas temperature and the initial air temperature and is more effected by the air temperature than by the gas temperature. Under severe winter conditions it is sometimes necessary to increase the temperature of the incoming air by recirculating a portion of the heated air. This can be done without greatly affecting the performance of the heater, for although the temperature head is reduced, the transfer rate is increased due to the higher rate of flow of air.

The chart on the opposite page gives the relation of the temperature drop of the flue gases passing through the air heater and the rise in temperature of the air. In order to make this chart more widely applicable and to eliminate a number of variables, the curves are plotted for various ratios of air and gas. When the temperatures of the air and gas are known the chart may be used to determine the ratio of air to gas. Also when the temperature drop of gas and the gas to air ratio are known, the final temperature of the air may be determined. The methods are illustrated by the dotted guide lines. Thus, if the gas temperature drop were 210 deg. fahr. and the air temperature rise were 300 deg. fahr., the ratio of air to gas would be .75 when the specific heat of gas is .26.

The weight of flue gas per pound of fuel fired may be computed from the gas analysis as explained in a previous article of this series. The weight of air supplied per pound of fuel may be obtained by subtracting from the weight of gases, the weight of fuel gasified per pound of fuel fired. Thus, if the weight of gases is found to be 15.5 lb. and the weight of air supplied 14.6 lb. per lb. of fuel, the ratio of air to gas will be .94. If 75 per cent of the air is passed through the air heater, the ratio of air to gas will be .70. When the initial gas temperature is 500 deg. fahr. and the initial air temperature 80 deg. fahr., a reduction of 250 deg. in gas temperature corresponds to an air temperature rise of 384 deg. The following temperatures are therefore obtained:

gas to heater	500 deg. fahr.
gas from heater	250 deg. fahr.
air to heater	80 deg. fahr.
air from heater	464 deg. fahr.

The mean specific heat of gases in the above example is assumed as .26. A chart giving specific heats of gases for various fuels was presented in the preceding article of this series.

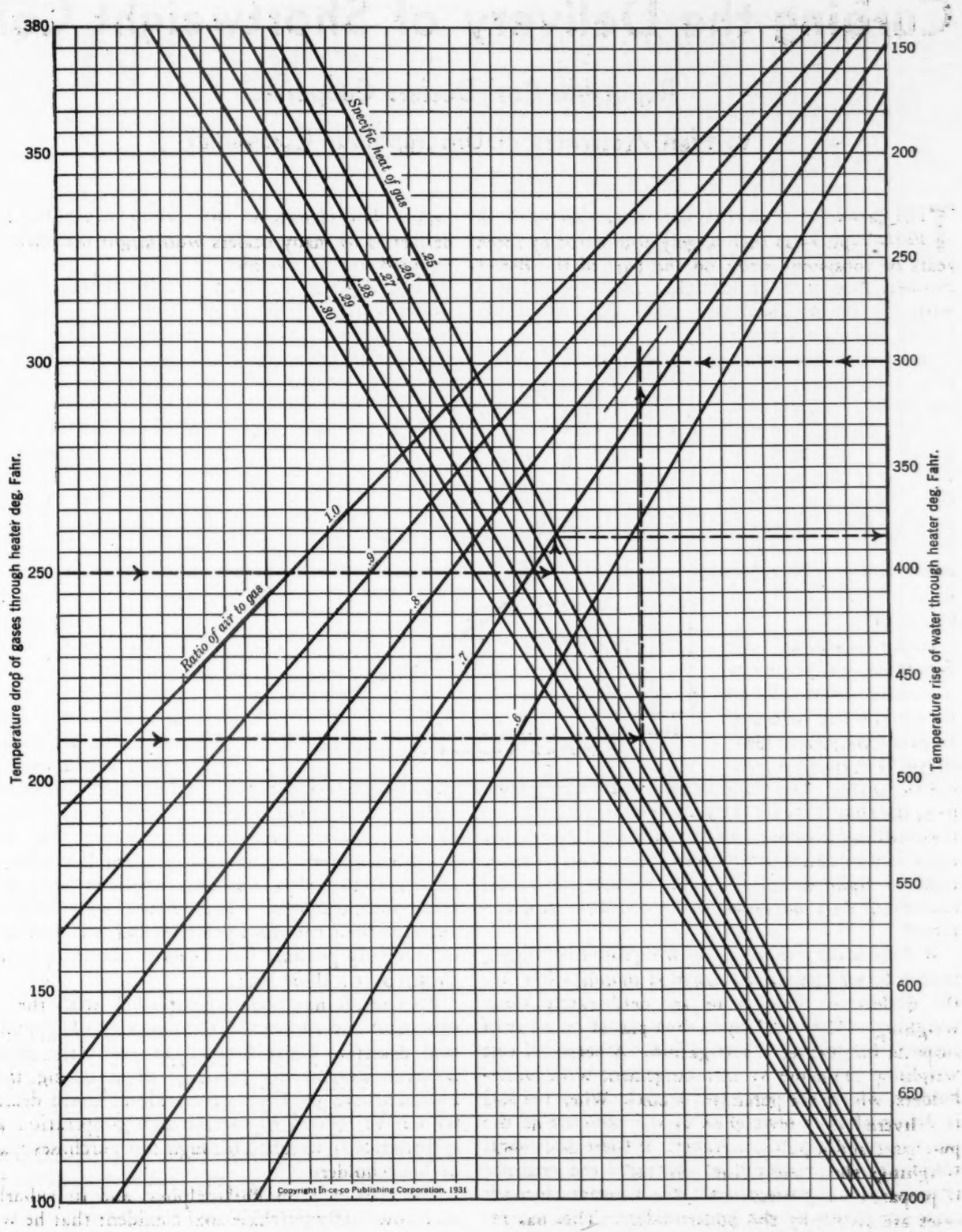


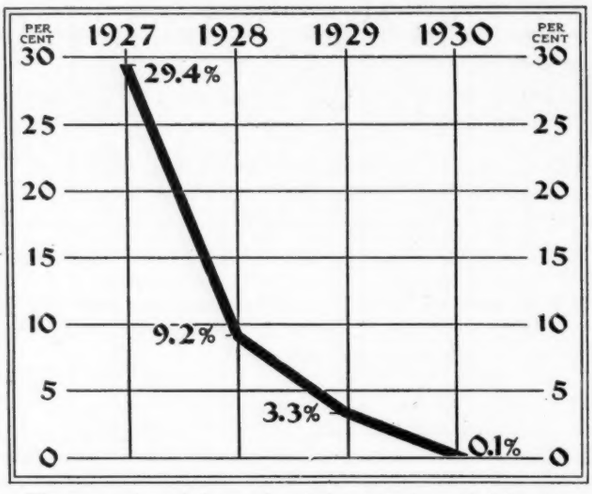
CHART SHOWING THE RELATION OF GAS TEMPERATURE DROP TO AIR TEMPERATURE RISE FOR AIR HEATERS

No. 18 of a series of charts for the graphical solution of steam plant problems.

Curbing the Delivery of Shortweight Coal

Reputable Coal Dealers Cooperate to Halt Activities of Unscrupulous Companies

THE problem of shortweight coal deliveries in Philadelphia has been largely eliminated by three years of consistent work on the part of the Better Business Bureau of Philadelphia which is affiliated with the Better Business Bureaus throughout the United States and Canada. In 1927 when the corrective campaign was inaugurated, 29.4 per cent of the loads weighed were found to be short. In 1930, only one-tenth of one percent were underweight. This represents a great saving to the consumer and a definite protective service to the honest dealer.



Three years' work has reduced shortages in coal deliveries from 29.4% to one-tenth of one per cent

Each working day throughout the year a representative of the Better Business Bureau visits coal yards and weighs the loaded trucks as they are leaving the scales. The truck is kept under observation from the time it leaves the yard until its return to see that nothing is done to alter its weight. The empty truck is then reweighed on the same scales to ascertain the light weight. In this manner the actual amount of coal delivered to the consumer is determined.

If these scale weighings show repeated shortages, as they sometimes do, it is taken as an indication that the dealers are careless or are deliberately short weighing. The company is then placed on a list of suspects for further investigation. A series of test weighings are made by an arrangement with householders, who make purchases of coal. When the fuel is delivered it is reweighed in the presence of the purchaser and a public weigher. If these additional weighings show substantial shortages the evidence is prepared for prosecution. The warrants in such cases are sworn by the householders. This has resulted in a number of coal dealers being convicted for giving short weight.

The dealers have no knowledge at what moment the Better Business Bureau investigator will weigh their trucks because he does not follow any prearranged route. He may weigh the first load which leaves the yard in the morning or the last load at night. This element of uncertainty insures full load deliveries by many dealers who might otherwise be tempted to short weight.

Such a program constructively combines educational work with punitive action. If the facts unmistakably show that a dealer is deliberately defrauding his customers there is no mercy shown in the action which follows. When convictions are secured the results are given wide publicity, reaching thousands of consumers. It is only a hardened swindler who will take sufficient chances with his business to hazard the very definite consequences of short weight which the Philadelphia dealer now faces.

The results attained in this field are an example what may be accomplished when business men determinedly seek to purge their industry of racketeering elements. The short weighting racket has been practiced by only a comparatively small number of unscrupulous dealers, who were rapidly bringing their trade into disrepute. They have been forced to abandon their nefarious practices and it is now only occasionally possible for the most daring operators to slip over a short load.

This result has been accomplished with the cooperation and support of the majority of reputable coal dealers. These firms have given the Better Business Bureau the privilege of weighing their loaded trucks on their own scales. Those dealers who have refused to extend such cooperation are systematically weighed through test purchases made by householders.

The consumer, in Philadelphia, and its suburbs, may now safely purchase coal confident that he will receive the amount of fuel which he ordered and for which he paid.

The fact that the practice of delivering light loads obtained to such an amazing extent in Philadelphia suggests the importance of investigating this situation in other large cities. Philadelphia's record should serve in extending this important work.

NEWS

Pertinent Items of Men and Affairs

California Oil Operators Vote to Reduce Output

At a general meeting December 17, the operators' committee of the California oil industry voted to reduce the state's allowable output, effective January 1, to 500,000 barrels daily, or 40,000 barrels daily less than the present limit of 540,000 barrels daily. Actual production in all California fields for the week ended December 13, according to the American Petroleum Institute, was 611,700 barrels daily, compared with 693,100 barrels daily in the same week a year ago. No excess production will be permitted and immediate curtailment of more than 100,000 barrels daily will be required of all operators, according to a statement made by the committee.

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Illinois Stoker Company, Alton, Illinois, has established an Eastern sales office at 30 Church St., New York City, with Alex Girtanner in charge.

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Heat Utilities Corporation, recently organized, 5 Beekman St., New York City, has acquired all patents covering the Simplex pulverizer, which were formerly owned by Furnace Engineering Company, a subsidiary of International Combustion Engineering Corporation, also patents and patent applications pertaining to the Uni-Flo pulverizer, formerly owned by Dr. Paul A. Hirsch and Warren C. Drake, who is president of the new company.

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Dr. George Otis Smith, who has been director of the United States Geological Survey since 1907, has been named chairman of the new Federal Power Commission by President Hoover. FRANK MCNINCH, of North Carolina, former mayor of Charlotte, has been nominated for the remaining place on the commission. The three other members named prior to the close of the recent session of Congress, were: FRANK B. WILLIAMSON, of Washington; COL. MARCEL GARSAUD, of Louisiana; and CLAUDE L. DRAPER, of Wyoming.

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The New England Public Service Company, recently put into service at Bucksport, Maine, the power ship JACONA which has been equipped by the company as a movable auxiliary plant to give standby service to its subsidiary electric light and power companies.

The Dampney Company of America, Hyde Park, Boston, Mass., manufacturers of APEXIOR Protective Coatings for power plant equipment, announces the opening of a direct Company Branch Office at Monadnock Block, 53 West Jackson Blvd., Chicago, Illinois, to serve the Middle West Territory. R. G. Ingram, J. D. Bird and C. M. Boling of the Dampney Company will have their headquarters in Chicago.

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William G. Christy, formerly mechanical engineer of the Board of Education of St. Louis, has been appointed Engineer in charge of the recently organized Smoke Abatement Bureau of Hudson County, New Jersey, a new department of the Board of Health of Hudson County. A smoke campaign will be conducted in cooperation with Stevens Institute of Technology, Hoboken, N. J., where Colonel Elliott H. Whitlock, for the past six years Smoke Commissioner of Cleveland, Ohio, has been appointed chairman of Smoke Abatement Research. Col. Whitlock will coordinate all smoke suppression activities in various counties and municipalities of New York, New Jersey and Connecticut with the smoke abatement campaign of New York City. Hudson County is appropriating $40,000.00 to finance the first year's work.

Chicago Power Show February 10 to 14, 1931

WHILE the meetings of the Midwest Power Engineering Conference and the Fuels Division of the American Society of Mechanical Engineers are being held at the Stevens Hotel, in Chicago, February 10 to 14, over 240 manufacturers of power equipment and appliances will be showing their products at the Chicago Coliseum.

Foremost power engineers and executives, representing leading companies and industries of the United States, will address the various sessions on the latest developments in their particular fields. Power economies, prime movers, developments in the steam and electrical fields, water problems of power plants, and other such topics will be discussed at the Power Conference sessions, while the Fuels Meeting wrn delve into the use of refinery waste fuels in modeill steam plants, developments in the small stoker field, new developments in furnace design, and other topics dealing with fuel utilization.

With over 240 exhibitors already committed, indications are that the entire 85,000 square feet of space in the Coliseum will be filled with a cross-section of the latest developments in power plant equipment, making the Exposition a source of authentic information for the engineers and power plant executives who are constantly seeking new means of increasing efficiency.

NEW EQUIPMENT

of interest to steam plant Engineers

Self-Contained Variable Speed Drive

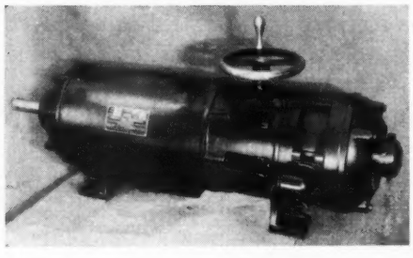
A UNIQUE variable speed drive, which combines motor, speed changer, speed reducer and control in a single housing has just been announced by Stephens-Adamson Mfg. Co., Aurora, Ill.

The new drive is extremely compact, easily mounted, quiet and is claimed to be very efficient due to the elimination of bearings, couplings and at least two sets of gear reductions. It is made in sizes to deliver from ¼ hp. to 7.5 hp. and is recommended for driving feeders, conveyors, mixers, pumps and practically every application where a variable speed drive is needed.

The unit, as shown in the illustration, is a complete drive in itself. The motor section is usually wound to operate at 1200 r.p.m. and the drive will deliver the power at any speed between 24 and 144 r.p.m. or between 120 and 720 r.p.m. The output speed is increased or decreased while the machine is in motion by simply turning the small hand wheel on top of the housing.

The whole mechanism is enclosed in a single housing without any moving parts exposed except the output shaft, thus protecting both machine and operators from possible injury. The unit can be mounted in any position by means of four bolts.

The operation of the speed changer section of the new drive is simple and it is



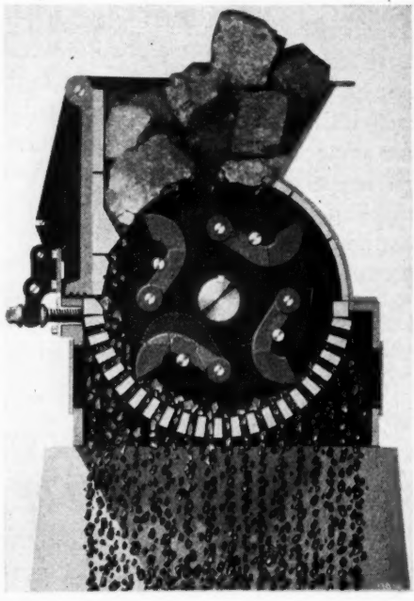
claimed that the transmission is absolutely positive under loads within the rated limits.

The new drive has several features which are summarized by the manufacturer as follows:

1—Motor is an integral part of drive.
2—Compact, as over 20 per cent of length is saved by eliminating coupling and several bearings.
3—Installation simple. Entire drive can be mounted in any position with but four bolts. No alignment and no special supports necessary.
4—Operates without vibration and almost without sound as couplings and at least two gear reductions have been eliminated.
5—No moving parts are exposed to endanger operators.
6—Long life, as mounting conditions are ideal and the variable speed reducer mechanism operates in oil, entirely protected from dust and atmospheric conditions.
7—The efficiency, already high, is increased by eliminating coupling and two bearings. All motor and transmission bearings are ball bearing.

Coal Crusher

THE Jeffrey Manufacturing Company, Columbus, Ohio, recently announced the development of the Jeffrey Flextooth Coal Crusher. This machine is a slow speed crusher of the single roll type and was designed especially for reducing coal and similar materials to uniform sizes, smaller than can be readily produced by the ordinary roll type

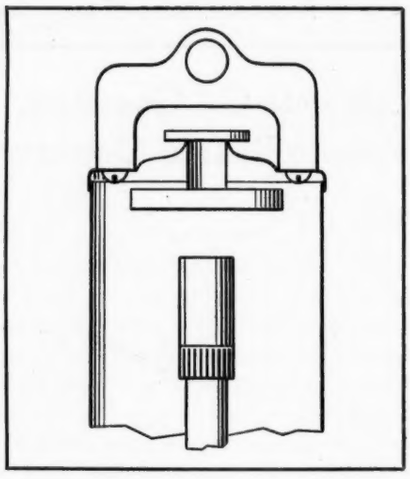


crusher. The accompanying illustration shows the cross section through the crusher. The teeth are kept in their outward position by centrifugal force. These teeth are so designed that this outward position is maintained at very slow speed but when coming in contact with tramp iron or very hard material of any kind, the teeth are free to swing back allowing the points of the teeth to disappear below the outer face of the crusher roll. This feature is a protection against breakage from foreign material getting into the crusher. The teeth are of steel and are made renewable. A hinged breaker plate allows easy access to all working parts and the large screening area assures large capacity of uniform product. The crusher is of rugged construction and simple design. Seven sizes are available, having capacities from 5 to 350 tons per hour, depending upon the fineness to which the coal is to be crushed. Run of mine coal is successfully reduced by this crusher in one operation to sizes ranging from 1¼ in. to 2 in. with a minimum amount of fines.

A New Draft Gage Seal

FOR sealing gasometer bell type draft gages against drawing out oil under periods of excess minus drafts, a "Check Seal" has been developed by Lewis M. Ellison of the Ellison Draft Gage Company, Chicago.

The seal is built into the top of the bell and consists of a double check-valve, one above and one below the bell head, as shown by the accompanying illustration. On the downward movement of the bell, a trifle in excess of the scale range, the disc below the bell head closes over the end of the draft tube, shuts off the draft from the bell, releases any excess through the top check, and holds only the established draft in the bell

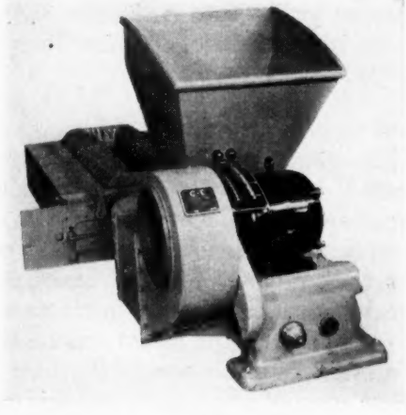


until normal operating conditions are restored. The double action check insures positive sealing for any suction head under all conditions.

This check seal may also be installed in bells of plus readings where the pressure may change momentarily from minus to plus, or where the induced draft fan is started up ahead of the forced draft fan.

Small Stoker Unit

COMBUSTION ENGINEERING CORPORATION, 200 Madison Avenue, New York, has placed on the market the C-E Stoker Unit which is a self-contained underfeed stoker with electric drive and integral fan construction. This stoker has been developed to provide a simple automatic machine for the firing of small boilers up to 150 hp. This stoker has a number of features not available in other machines of this size, such as, agitated grate bars, side dumping grates and



agitated feed hopper which eliminates arching of the coal and interrupted feed. The design is self-contained, completely enclosed and provides a simple, rugged and dependable unit for the underfeeding of coal under small boilers. Three sizes are available with coal burning capacities of 300 lb., 600 lb. and 1000 lb. of coal per hour respectively.

Due to its unit construction, a C-E STOKER UNIT may be installed and placed in operation in 6 to 12 hours.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from
In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

A Handbook of English In Engineering Usage

By A. C. Howell

PROFESSOR HOWELL takes a very practical point of view with regard to the engineer's professional use of language. He says in the preface to this handbook that, for the majority of engineers, English is primarily a tool for professional advancement. His book reflects this attitude throughout.

Chapters are devoted to word usage and idioms, sentence and paragraph structure, composition, punctuation and the mechanics of writing, and grammar. The treatment throughout is simple; the matter is well arranged, and numerous examples are given. The latter part of the book is devoted to writing in connection with letters, reports and technical articles.

Most engineers today have occasion to do considerable writing and for those who have some doubt as to their ability to express themselves clearly, accurately and in acceptable form, Professor Howell's book will be of very definite value, both for study and reference.

This book is 5½ by 7½ overall and contains 308 pages, including a very comprehensive index, which facilitates reference through the use of a decimal system. The price is $2.50.

Heat Engines

By Charles N. Cross

THE material comprising this book was originally assembled for use in a lecture course for mechanical engineering students at Stanford University. In its present form, it represents several years of evolutionary development.

While quite a number of books have been published on this general subject, Prof. Cross' book appears to be particularly practicable both for the student and the operating engineer, because a goodly part of it is devoted to equipment which exemplifies the practical application of the theories discussed.

For student use, the material in this book is sufficient for a thorough four unit course extending through the college year. By the omission of certain sections which are set in slightly smaller type and which constitute approximately one-third of the text, the essentials may be presented in an abridged course for non-mechanical engineering students.

The contents of this volume include a fairly comprehensive treatment of the fundamental laws of gases and the laws of thermodynamics, together with descriptions of the modern forms of prime movers, their operating characteristics and typical performance of the various types and sizes of each. The chapters on steam turbines and internal combustion engines are developed more completely than is generally the case in other books of this type.

The first part of the book is devoted to theory and basic laws under chapter headings such as, "Energy and Matter", "Heat and Work", "Fundamental Laws of Gases", "Transformation of Heat Energy into Mechanical Work and Specific Heats of Gases", "Gas Expansions", "Vapors and Their Properties", the final chapter of this part of the book being "Engine Cycles, Second Law of Thermodynamics, and Thermodynamic Scale of Temperature". The latter part of the book is devoted to fuels and combustion, steam boilers, engines and turbines, and internal combustion engines.

This book is 8¾ x 6 overall, and contains 607 pages, including a comprehensive index. The price is $5.00.

The Fuel Problem Of Canada

By Martin Nordegg

THIS is a very interesting little volume, which is evidently intended to stir up political agitation over the coal situation of Canada. The author discusses the various Canadian fields, the extent to which they are developed, the types of coals available, and the general situation with respect to each. His description of and comments on the methods of marketing and shipping would indicate that there is apparently much room for improvement.

There are also chapters on the Canadian situation with respect to petroleum, peat, natural gas and hydro electric power.

The whole substance and purpose of this book is summed up in the fact that while Canada possesses 17 per cent of the coal reserves of the world, she is the second largest coal importing country in the world, the United States alone receiving $130,000,000 annually for coal shipped into Canada.

This book is 5¼ x 7½ overall and contains 155 pages. The price, including duty, is $2.00.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Air-Cooled Furnace Walls

Catalog No. 30 is an attractive loose leaf booklet describing Economy Air-Cooled Furnace Walls. The illustrations are well chosen and the general information on furnace design will be of interest to all combustion engineers. Numerous illustrations show the application of various types of furnaces to different combinations of boilers and settings. The loose leaf feature provides for additional data sheets which will be released from time to time. 36 pages and cover, 8½ x 11—Furnace Economy Company, 407 South Dearborn Street, Chicago, Illinois.

Ash Storage Tanks

A new bulletin describes United Vitrified Glazed Tile Tanks for the storage of ashes. The design of this tank reflects an appreciation of the severe requirements of ash storage such as cleanliness, prevention of freezing, elimination of packing and arching in the tank, provision for reliable gravity unloading and resistance to corrosion, abrasion and heat. The catalog is well illustrated with photographs and line drawings and tables of standard dimensions and capacity are included. 16 pages and cover, 8½ x 11—United Conveyor Corporation, Old Colony Building, Chicago, Ill.

Automatic Control

"The Era of Automatic Control" is the title of a new booklet which describes Brown automatic control equipment for regulating temperatures, pressures, flow, liquid levels, etc. The booklet is devoted more particularly to emphasizing the application of control equipment to various branches of industry than to the description of specific instruments and devices. 32 pages and cover, 7¾ x 10½—Brown Instrument Company, Wayne and Roberts Avenues, Philadelphia, Pa.

Cinder Trap

The Green Cinder Trap is briefly presented in new bulletin No. 162. This device has been developed to remove cinders usually found in flue gases of stoker and hand-fired boiler plants. Test results show that as much as 96 per cent of the cinders has been removed at certain installations. This result is accomplished with low draft loss and high efficiency. 4 pages, 8½ x 11—Green Fuel Economizer Company, Beacon, N. Y.

Coal Crusher

New bulletin No. 510 describes the Jeffrey Flextooth Coal Crusher. This crusher is of heavy construction. It is equipped with renewable steel crusher teeth which are kept in an outward position by centrifugal force. These teeth being pivoted are free to swing back out of the way when tramp iron or other foreign material enters the crusher. This feature is a protection against breakage. Illustrations show the principle of design and the details of construction. A table of sizes is included to cover capacities from 5 to 350 tons per hour. 4 pages, 9½ x 10½—Jeffrey Manufacturing Company, Columbus, Ohio.

Combustion Recorders

Hays Combustion Recorders for CO_2, furnace draft and flue gas temperatures are presented in new catalog RA-31. The booklet is printed in three colors and numerous instrument charts are included to illustrate the applicability of this instrument to widely varying furnace and plant conditions. Details of design and operation of the recorder are clearly presented and comprehensive illustrations reveal the operating principle of the device. 24 pages, 8½ x 11—Hays Corporation, Michigan City, Ind.

Industrial Inspection Service

The Pittsburgh Testing Laboratory has just issued an attractive booklet "The Protective Value of Independent Inspections." A wide range of inspection service is covered and the experience and facilities of the organization are indicated by the diversified character of its inspection service which touches practically every branch of industry, including fuel analysis. 8 pages and cover, 8½ x 11—Pittsburgh Testing Laboratory, Pittsburgh.

Insulation

Bulletin No. 200 is called "Quick Facts about Gimco Pipe Covering." A wide range of rock wool insulation is presented and numerous photographs show the methods of applying the various forms of covering for different types of service. A chart is included to show the savings effected by the use of heat insulation with varying pipe sizes and temperature differences. 8 pages, 8½ x 11—General Insulating and Manufacturing Company, Alexandria, Ind.

Multiple Retort Stoker

Two new bulletins describing the Taylor Multiple Retort Stoker are available. A general catalog, printed in three colors, describes the Taylor stoker in detail and shows a number of typical installations. Test results on five installations are included. 24 pages and cover, 8½ x 11—American Engineering Co.

"New Horizons in Coal Burning" is a new booklet describing the development of the long Taylor stoker and the results secured with this type of machine at various central station power plants. A great deal of interesting technical information is included and the illustrations are comprehensive and well chosen. 40 pages and cover, 5½ x 8½—American Engineering Company, Philadelphia.

Power Plant Instruments

The Foxboro line of instruments in the power plant is presented in new bulletin No. 115-3. A very complete range of instruments is included, such as pressure gages, thermometers, flow meters, water level recorders, draft gages, CO_2 recorders and complete instrument boards. These various instruments are available in both indicating and recording types. An interesting feature is a two-page drawing of a typical power plant on which the locations of various steam plant instruments are indicated. 28 pages, 8½ x 11—The Foxboro Company, Foxboro, Mass.

Pulverizer

The Riley Atrita Unit Pulverizer is illustrated and described in a new bulletin. The details of construction are shown and numerous installation drawings are included to show the application of this pulverizer to the direct firing of various types of boiler furnaces. Considerable general information on the burning of pulverized fuel is presented. 28 pages and cover, 8½ x 11—Riley Stoker Corporation, Worcester, Mass.

Pulverized Fuel Equipment

Purfeco Pulverized Fuel Equipment and Systems are presented in General Catalog No. 4. A section devoted to the general discussion of fuels, furnaces and combustion, is followed by chapters in which specific types of systems and installations are illustrated and described. The equipment presented is not limited to Purfeco apparatus but includes various types built by different manufacturers. Much valuable engineering data is included in tables and charts. 62 pages and cover, 8½ x 11—Pulverized Fuel Equipment Company, 228 North La Salle Street, Chicago, Ill.

Steam Separators

Bulletin No. S-14-A illustrates and describes the Swartwout line of steam separators. Sizes and types are available for every type of service and range of pressure. The general description of steam separators is followed by dimension charts and illustrations pertaining to various designs and sizes of separators that are manufactured by this company. 12 pages 8½ x 11—Swartwout Company, 18511 Euclid Avenue, Cleveland, Ohio.

Tachometers

Brown Electric Indicating and Recording Tachometers are described in catalog No. 46 which is just off the press. A description of electric tachometers is followed by a discussion of the constructional advantages of the Brown instrument. Details of the machine are shown and various application arrangements are suggested. Both indicating and recording instruments are available in a number of types and applicable to various mountings. 16 pages and cover, 8½ x 11—Brown Instrument Company, Philadelphia, Pa.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

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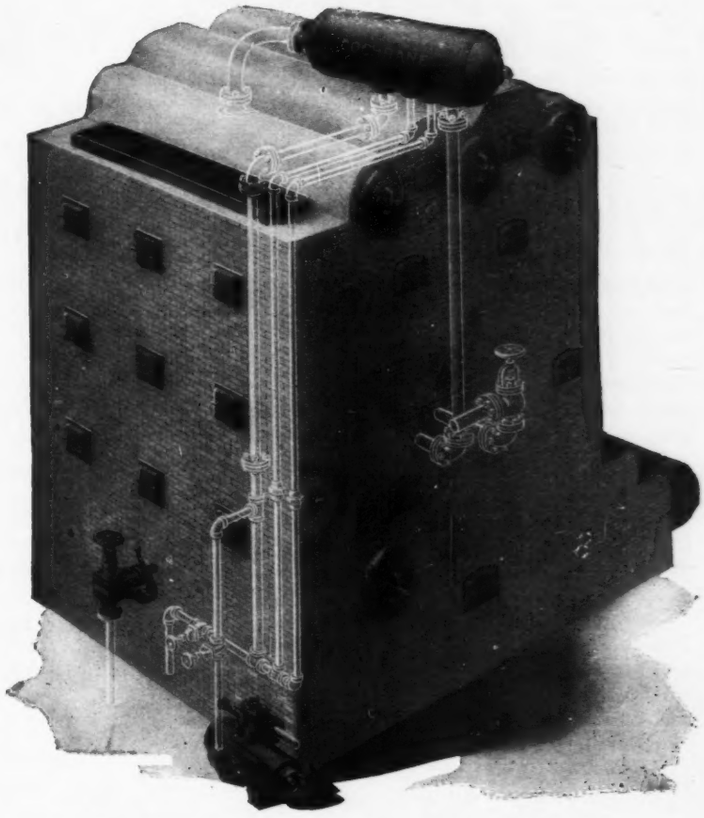

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The main object of this book is to give an outline of the chemistry of coal carbonization, as far as it is at present understood, from an academic rather than from a technical standpoint. Chapters are devoted to the early history and later development of coal carbonization, the action of heat on coal, coal gas, ammonia and its recovery, coal tar and the formation and properties of coke.

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Boiler, Stoker and Pulverized Fuel Equipment Sales

Total figures to November 1, as reported to the Department of Commerce by the leading manufacturers in each industry

Boiler Sales

	Total 10 mo. 1930		Total 10 mo. 1929		Oct., 1929		Oct., 1930	
	No.	Sq. ft.	No.	Sq. ft.	No.	Sq. ft.	No.	Sq. ft.
Water tube	975	5,126,016	1482	8,663,009	143	970,950	69	310,823
H.R.T.	796	1,075,376	1213	1,636,233	111	177,729	57	72,470

Mechanical Stoker Sales

Year and Month	Total		Type of Boiler			
			Fire-tube		Water-tube	
	No.	HP.	No.	HP.	No.	HP.
1929						
August	199	54,929	94	13,981	105	40,948
September	155	45,685	71	9,791	84	35,894
October	178	56,108	89	11,349	89	44,759
Total (10 mo.)	1,530	515,140	633	92,962	897	422,178
Total (year)	1,716	599,585	706	102,515	1,010	497,070
1930						
January	53	13,198	24	2,872	29	10,326
February	73	22,648	26	3,732	47	18,916
March	89	32,403	45	6,128	44	26,275
April	108	35,903	46	6,984	62	28,919
May	96	31,956	41	5,703	55	26,253
June	151	47,803	70	10,100	81	37,703
July	150	37,761	83	11,434	67	26,327
August	115	29,988	61	10,587	54	19,401
September	128	42,899	71	9,186	57	33,713
October	92	38,276	46	5,148	46	33,128
Total (10 mo.)	1,055	332,835	513	71,874	542	260,961

Pulverized Fuel Equipment Sales

Year and Month	CENTRAL SYSTEM			UNIT SYSTEM		
	No. of Pulverizers	Total Rated capacity in tons of coal per hour	Total Rated hp. of boilers equipped	No. of Pulverizers	Total Rated capacity in tons of coal per hour	Total Rated hp. of boilers equipped
1930	For Installation Under Water-Tube Boilers					
January	1	6	1,600	52	565	59,742
February	2	20	3,000	29	175	23,305
March	2	50	6,414	16	33	9,995
April	....	....	....	31	139	37,993
May	3	80	11,360	30	196	22,625
June	1	6	802	15	28	7,146
July	2	22	1000	12	29	20,424
August	....	....	....	4	13	1,454
September	....	....	....	24	112	18,729
October	....	....	....	10	16	3,499
Total (10 mo.)	11	184	24,176	223	1,306	204,912
	For Installation Under Fire-Tube Boilers					
January	....	....	....	6	35	965
February	....	....	....	2	13	305
March	....	....	....	3	3	450
April	....	....	....	3	3	780
May	....	....	....	....	....	....
June	....	....	....	....	....	....
July	....	....	....	....	....	....
August	....	....	....	3	3	712
September	....	....	....	6	3	900
October	....	....	....	....	....	....
Total (10 mo.)	....	....	....	23	60	4,112

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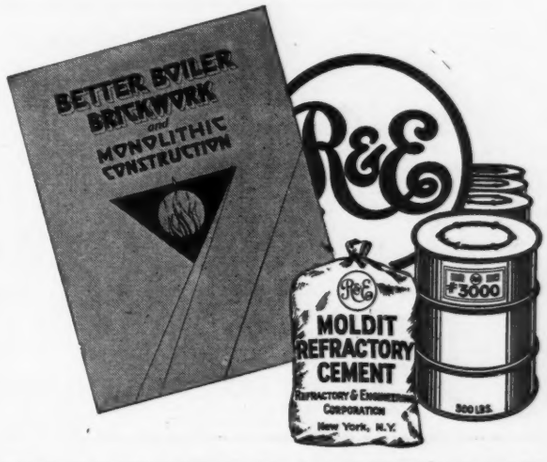

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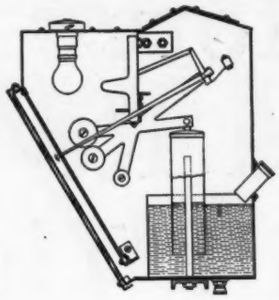

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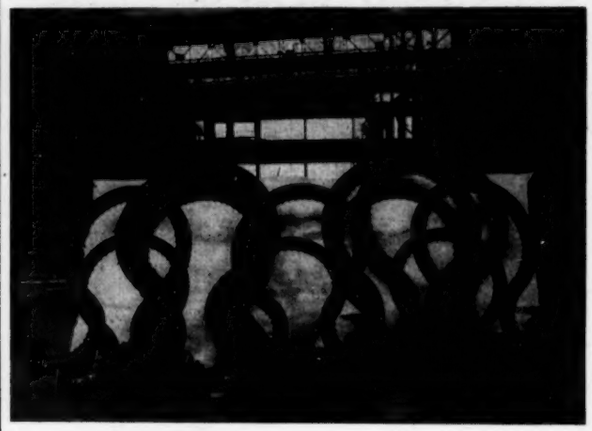

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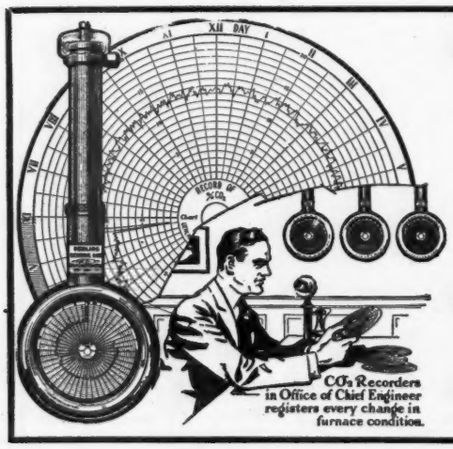

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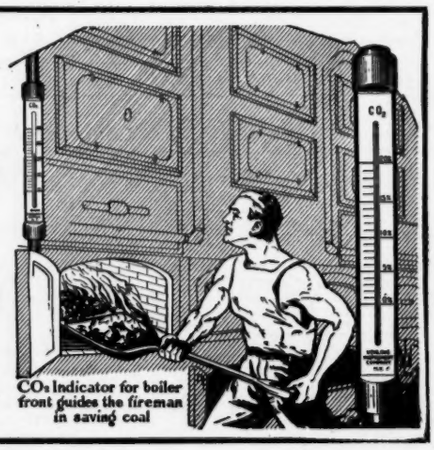

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